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MAKING AMERICAN CHEDDAR CHEESE of Uniformly Good Quality from Pasteurized Milk

U. S. Department of Agriculture

Circular No. 880

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May 1951 • Washington, D. C.

UNITED STATES DEPARTMENT OF AGRICULTURE

Making American Cheddar Cheese of Uniformly Good Quality from Pasteurized Milk[1, 2]

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CONTENTS

Page
Introduction 1
Development of pasteurization in manufacturing Cheddar cheese 2
Quality of milk 5
Pasteurizing the milk and avoiding recontamination 7
Startermaking 11
  Startermaking equipment 11
  Quality of starter milk 13
  Sterilizing the starter milk 13
  Preventing contamination 14
  Incubation temperature 14
  Uniformity of procedure 14
The time-schedule method 15
  Development of acidity 15
Using the clock to systematize cheesemaking 17
Manufacturing procedure 18
  Pasteurizing the milk 18
  Adding the starter 18
  Adding the rennet (setting) 19
  Cutting the curd 20
  Heating or cooking the curd 22
  Diping (draining the whey) 23
  Ditching and packing the curd 23
  Cheddaring or matting the curd 24
  Titrating the acidity of the whey 27
  Milling the curd 27
  Salting the curd 28
  Hooping the curd 29
  Pressing the curd 31
  Dressing the cheese 31
  Removing the cheese from the press 31
  Drying the cheese 32
  Paraffining the cheese 33
  Boxing the cheese 33
  Grading the cheese 34
  Curing the cheese 34
Composition and yield of cheese 35
Using whey and butterfat by-products 36
Literature cited 37

INTRODUCTION

To manufacture Cheddar cheese of uniformly good quality from pasteurized milk it is essential to use (1) good quality milk,

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[1] The authors wish to acknowledge the work of L. A. Rogers and H. L. Wilson, who were responsible for the development of the Bureau's time-schedule method of making American Cheddar cheese from pasteurized milk.

[2] The photographs in this circular were supplied by The Borden Cheese Company, Kimble Glass, and Kraft Foods Company.

[3] Retired September 30, 1950.

(2) sanitary equipment, (3) controlled pasteurization, (4) a uniformly active starter, and (5) a standardized manufacturing procedure.

This circular discusses these five principal requirements briefly and describes in detail a manufacturing procedure which is being used successfully in many factories. This manufacturing procedure is known by different names in different factories—the time-schedule method, precision cheesemaking, or making cheese by the clock.

The information in this circular is presented as a guide for use in factories where the milk is being pasteurized or where the installation of a pasteurizer is being considered, and also for use by prospective cheese manufacturers who plan to make cheese from pasteurized milk.

DEVELOPMENT OF PASTEURIZATION IN MANUFACTURING CHEDDAR CHEESE

Von Freudenreich (*8*),[4] in 1892, was among the first to recognize and investigate the possibility of improving milk for cheesemaking by pasteurizing it. It was recognized then that pasteurization would destroy nearly all of the micro-organisms in milk, but little was known about the harmful effects of overheating the milk or the necessity of using a bacterial starter. Between that time and 1907, other experimenters in Europe (*7*) and in Canada (*4, 5*) attempted to make cheese from pasteurized milk but obtained generally unsatisfactory results.

In the United States the early work on pasteurization of milk for cheesemaking dealt principally with its effects on disease-producing organisms. In 1909, Mohler et al. (*18*) demonstrated that the organism that causes tuberculosis can stay alive for weeks in cheese and stated that—

> If it be possible to use pasteurized milk in the manufacture of cheese without injuring the product, a simple solution of the problem is offered to the cheese manufacturer in the process known as pasteurization.

The first well-controlled experiments in making Cheddar cheese from pasteurized milk were begun cooperatively in 1907 by the University of Wisconsin and the United States Department of Agriculture. The results were reported by Sammis and Bruhn in 1912 (*30*). Bacterial starters were used, and a time schedule for each step in the cheesemaking process was proposed. But the heat treatment diminished the rennet-coagulating property of the milk, and it was necessary to add acid to restore normal coagulation.

Meanwhile, methods of controlling the temperature in pasteurizing equipment were being improved. In 1910, Publow (*27*) described a method which was said to be successful for making cheese from milk pasteurized at a controlled temperature and with calcium chloride and lactic starter added. A report in 1916 (*28*) of additional experiments by Sammis, with milk pasteurized at a controlled temperature, indicated that high-quality cheese could be made from pasteurized milk without the addition of acid and that pasteurization of the milk and the use of a lactic starter eliminated the harmful effects of gas-producing bacteria and improved the flavor of the cheese. In 1913 and 1915, Benson and Evans (*2, 1*) in England reported the development of a continuous pasteurizer and stated that pasteurization improved the quality of cheese when the milk was not overheated.

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[4] Italic numbers in parentheses refer to Literature Cited, p. 37.

Commercial pasteurization of cheese milk was begun in New Zealand in 1912. High-temperature, short-time pasteurizers capable of maintaining the temperature between 160° and 165° F. were imported from Denmark in 1914. The use of lactic starters was found necessary. Stevenson and Grant (*36*) reported in 1916 that factory operators in New Zealand were adopting the pasteurizing process rapidly and were fully convinced of its benefits. Stevenson (*34*) stated in 1920 that pasteurization was especially effective in overcoming the difficulty with overripe milk, and he emphasized the importance of precise control of the pasteurizing temperature. He reported in 1924 (*35*) that approximately two-thirds of the cheese being manufactured in New Zealand was made from pasteurized milk and that the method was an unqualified success.

During 1926 to 1929, a number of investigators in the United States reported experiments showing that good-quality Cheddar cheese could be made successfully from pasteurized milk (*15, 16, 20, 22, 23, 26*). Price (*22, 23*) described an approximate time-schedule method, but specified more variation in the time of each operation than is recommended in the method described in this circular. He confirmed the earlier results of Sammis and Bruhn and added the significant observation that, while pasteurization is more effective when the quality of the milk is poor, the quality of pasteurized-milk cheese varies with the quality of the raw milk. Marquardt (*15*), using both the holding and the flash methods, found that pasteurization made different lots of milk more uniform in their properties and produced distinct improvement in the quality of the experimental cheese. Phillips (*20*) demonstrated that pasteurization made the cheese more uniform and produced the greatest improvement when the raw milk was of poor quality and when it was gassy.

Although pasteurized-milk cheese had been made successfully on an experimental scale in the United States prior to 1929, the pasteurizing process had not been accepted generally by the cheese-making industry up to that time, partly because its use involved additional equipment and changes in the manufacturing method.

Specialists in the Bureau of Dairy Industry began to conduct pasteurization experiments in the laboratories and to introduce the results in several factories in southern States in 1927. More intensive work was done in the laboratories, beginning in 1931, and in factories in Washington and Oregon in 1935 and in Wisconsin in 1938-39 (*45*). The results showed that pasteurization of the milk, except when it was of very good quality, improved the quality of the cheese. Gassiness was eliminated almost entirely and off-flavors were reduced greatly. The improvement was greatest when the milk was of poor quality. The pasteurized-milk cheese was much more uniform in quality and somewhat more uniform in composition than raw-milk cheese. Pasteurization of milks of different quality made them comparatively uniform in the physical and bacteriological properties that influence the cheesemaking process.

More significantly, tabulations of acidity data and grades for about 100 lots of cheese made in the Bureau's laboratories and for about 600 lots made in commercial factories showed that the quality of the cheese depended not only on the amount of acid developed during the making process but also on the rate of acid development. The proportion of good-quality cheese was greatest in those lots in which the development of acidity at definite stages was controlled within specified limits—that is, when it was not too slow and inadequate and especially when it was not too rapid and excessive.

These tabulations and their significance have been reported in detail (*45*, *41*). The results confirmed those obtained earlier by Brown and Price (*3*) in experiments with raw milk, by Spicer and Burgwald (*33*) with both raw and pasteurized milk, and by Phillips (*21*) with pasteurized milk. They agree also with general statements by Thom and Fisk (*38*).

Furthermore, the Bureau's technologists found that the rate and amount of acid development could be controlled within the optimal limits most conveniently and with greatest uniformity by following a definite time schedule for each step in the making process (see fig. 7, p. 17). A preliminary description of the time schedule method of making Cheddar cheese from pasteurized milk was published in 1941 (*42*), and more detailed descriptions were published in 1942 (*43*) and in 1949 (*14*).

During World War II, in an effort to increase the production of U. S. No. 1 cheese in the United States, the Bureau began an intensive program of introducing the method in factories that requested help. The method was introduced in about 160 factories in 9 States—Arkansas, Illinois, Indiana, Kentucky, Michigan, Minnesota, Missouri, Ohio, and Tennessee. Use of the method produced consistent improvement in quality and uniformity of cheese (*41*). For example, in a group of 11 representative factories, the proportion of No. 1 cheese was raised during the introductory period from about 25 percent to 86 percent; and during the first 8 months following introduction of the method, the proportion of No. 1 cheese increased to between 94 and 100 percent. These results are typical of the improvement made generally in the factories where the method was introduced, and particularly in those factories that formerly had been producing a large proportion of poor-quality cheese. Since then the method has been adopted widely.

A survey made in 1949 by the National Cheese Institute (*19*), in 20 of the leading cheese-producing States, showed that 71 percent of the 1,900 factories, making 80 percent of the American-type cheese, were equipped to pasteurize the milk. In 11 States, all the factories making American-type cheese were equipped to pasteurize the milk.

Janzen and Brown (*13*) reported that the average quality of experimental cheese made in Canada was improved when the milk used in making the cheese was pasteurized.

Descriptions of the manufacture of Cheddar cheese from pasteurized milk have been published recently (1948-51) in textbooks on cheesemaking (*29, 40, 46*) and also in publications by the Wisconsin and Nebraska Agricultural Experiment Stations (*6, 24*) issued in 1944 and 1948.

Many States have adopted regulations requiring that Cheddar cheese either be made from pasteurized milk or be cured for a definite length of time—usually at least 60 days. Federal standards of identity for cheese, issued in 1950 by the Food and Drug Administration, include a regulation requiring that if the milk used in making Cheddar cheese is not pasteurized the cheese must be cured for not less than 60 days at a temperature not lower than 35° F. These regulations were adopted as a safeguard against possible transmission of disease-producing micro-organisms through the consumption of cheese.

QUALITY OF MILK

Cheddar cheese of good quality can be made from either raw or pasteurized milk if the quality of the milk is good. But cheese of the best quality **cannot be made from poor-quality milk** even though the milk is pasteurized. Bacterial changes resulting from contamination of the raw milk are always more or less detrimental, and they are most rapid when the milk is held without sufficient cooling. Although pasteurization destroys nearly all the undesirable as well as nearly all the desirable micro-organisms (bacteria, yeasts, and molds), it does not undo all the harmful effects produced by those that were present and growing in the milk before it was pasteurized.

It is especially important for the cheese-factory operator to advise the patrons concerning approved sanitary practices and to make certain that all patrons deliver good milk.[5] The milking machine, pails, cans, strainer, and other utensils should be rinsed, washed thoroughly, and scalded or sterilized immediately after use, and the containers should be placed on a rack where they will drain and dry quickly. Cans used for transporting whey should be cleaned thoroughly and then sterilized. (In some States it is illegal to deliver milk in cans in which whey has been transported.) Treating the cleaned containers with a chlorine disinfecting solution just before use, and then draining them thoroughly, is an additional and effective sanitizing method.

It is essential that producers **cool all milk promptly** and keep the evening milk cold overnight. It can be kept cold conveniently by placing the cans of milk in a tank of cold, flowing water. Warm milk should not be mixed with cold milk.

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[5] For more information on the production of clean, good-quality milk, see U. S. Department of Agriculture Farmers' Bulletin 2017, Clean Milk Production.

It is advisable to have the producers deliver the evening milk and the morning milk in separate cans. The milk should be delivered early in the morning, and manufacture of the cheese should begin promptly.

Every can of milk should be graded at the intake (figure 1).

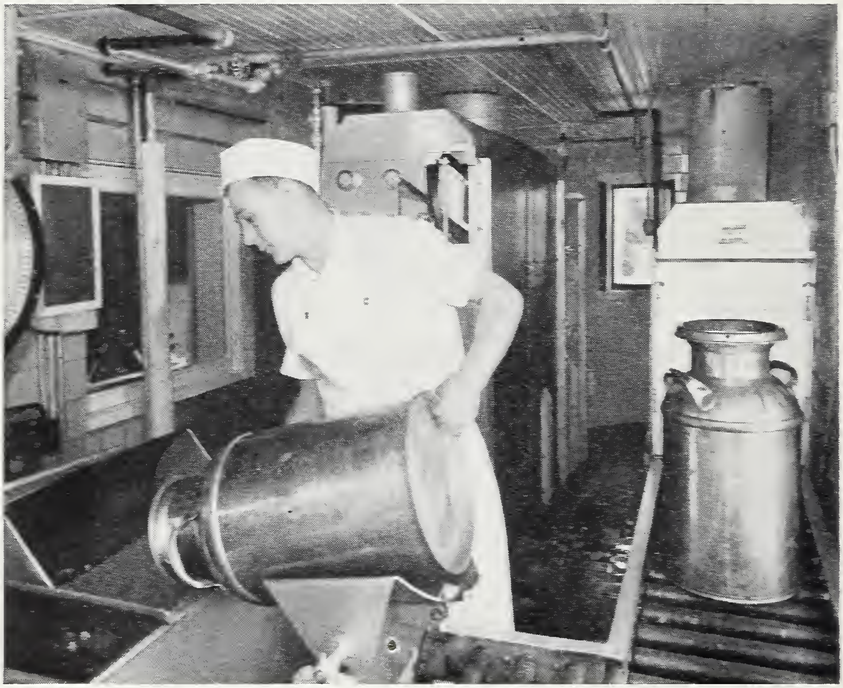

FIGURE 1.—Receiving and dumping the milk. The milk is graded and dumped through a strainer into the weighing tank, where it is weighed and a sample is taken. The empty cans and covers go through the can-washing machine, in which they are cleaned and steam-sterilized.

All the milk should be fresh. It should have a fresh, sweet, clean aroma and flavor, and no unclean odor or evidence of developed acidity. As a rule, the percentage of titratable acidity of the milk in any can should not be more than 0.03 greater than that of fresh, normal herd milk for the breed and the locality. In any case, even in high-solids milk, the acidity of the milk in any can should never exceed 0.21 percent and the acidity of the milk in any vat should never exceed 0.19 percent. These maximum figures should be lower in low-solids milk, because the titration value depends partly on the percentage of solids in the milk.

The milk should be free of excessive sediment. If the milk delivered by any patron contains more than 2.5 milligrams of sediment[6] in a 1-pint sample taken from the bottom of the can, it should be rejected. It must be free of gross bacterial contamination. The methylene-blue reduction time of the milk should not be less than 3½ hours, and corrective steps should be taken if that of the milk of any patron is less than 1 hour. It is especially important that the milk be as free as possible of gas-producing bacteria.

Milk from cows that have mastitis should not be used for making cheese. It is abnormal in composition and properties—particularly in that it coagulates slowly with rennet and forms a relatively soft, high-moisture curd and weak-bodied cheese. The use of a rennet-coagulation test—for example, the Marschall rennet test—is recommended to determine whether or not the milk will coagulate normally. The vat milk, and occasionally the milk delivered by each patron, should be tested.

Milk from mastitis-infected cows whose udders are being treated with penicillin, aureomycin, or other antibiotics usually contains enough of the therapeutic agent to inhibit normal starter growth. Such milk has been found to cause serious difficulty in cheesemaking. The actual length of time that must elapse before milk from treated cows can be safely included in the cheese milk cannot be stated definitely. It depends on the kind and amount of antibiotic used in treating the cows, and on other related factors. Some workers have found that the milk should not be used until at least the third or fourth milking after certain treatments. Others, investigating different treatments, state that it should not be used until at least the sixth milking or even after much longer periods.

PASTEURIZING THE MILK AND AVOIDING RECONTAMINATION

Pasteurization is defined by the U. S. Public Health Service as "the process of heating every particle of milk . . . to at least 143° F., and holding at such temperature for at least 30 minutes, or to at least 161° F., and holding at such temperature continuously for at least 15 seconds, in approved and properly operated equipment: *Provided,* That nothing contained in this definition shall be construed as disbarring any other process which has been demonstrated to be equally efficient and is approved by the State health authority." [7]

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[6] Sediment standards for milk to be used in cheesemaking can be obtained from the National Cheese Institute, 110 N. Franklin St., Chicago 6, Ill. The United States Department of Agriculture has issued sediment standards for milk and milk products, for use in educational programs for improving the quality of milk and milk products. The chart shows 12 disks, and the number under each disk shows the amount of sediment (ranging from 0 mg. to 2.5 mg.) in a pint of milk. Copies of the chart (BDI–1098) can be obtained from the Bureau of Dairy Industry.

[7] This definition was published by the U. S. Public Health Service in a processed leaflet entitled "Revised milk ordinance recommended by the Public Health Service," dated April, 1949, and supersedes the definition that appeared in the 1939 edition of U. S. Public Health Bulletin No. 220, "Milk ordinance and code."

For factories with more than one cheese vat, the regenerative, continuous, high-temperature, short-time (HTST) method of pasteurization is more rapid and mechanically more efficient than the holding or vat method, and the pasteurizer occupies less space. The HTST method of pasteurization requires an automatic temperature control and recorder, and a pump producing a fixed rate of flow. It also requires a holding pipe of correct dimensions to hold the hot milk for at least the specified time; and it should have a flow-diversion valve, at the discharge end of the holding tube, to return any under-heated milk through the pasteurizer automatically.

The plate-type pasteurizer (fig. 2) and the tubular pasteurizer (fig. 3) are continuous, regenerative HTST types.

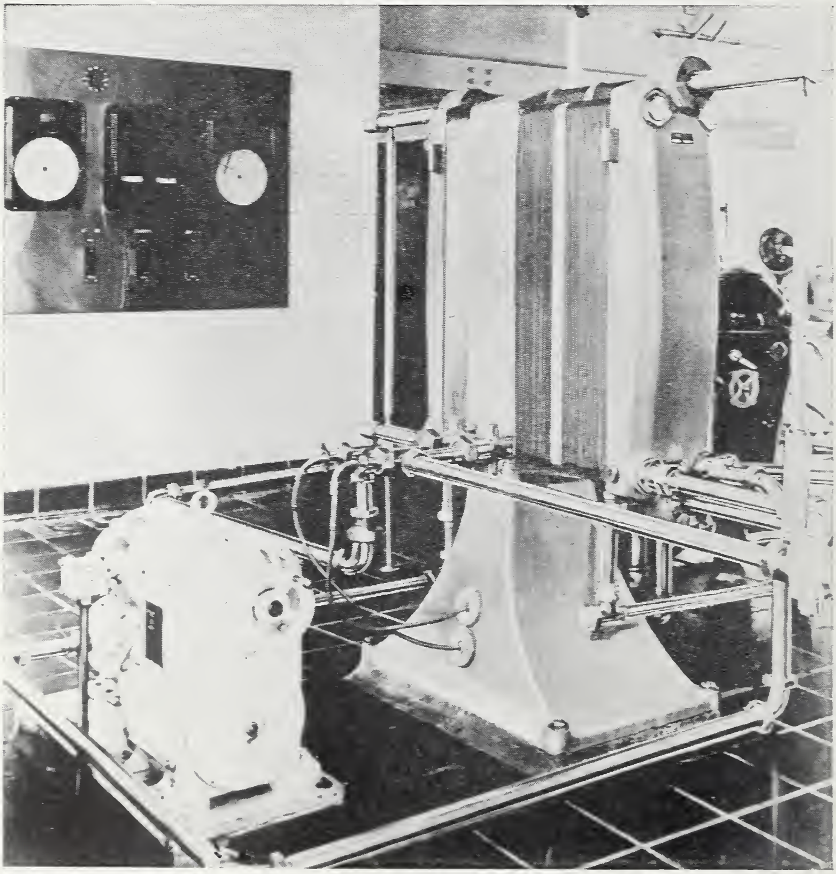

FIGURE 2.–Plate-type, regenerative, high-temperature, short-time pasteurizer, with pump (left) and controls on wall.

No part of the pasteurizer or other equipment that comes in contact with the milk should be made of copper, because copper from the equipment may be dissolved in the milk. Experiments (*37*) have shown that even a small quantity of copper in the milk is very harmful to the quality of the cheese. Copper retarded the rate of flavor development and caused unclean, metallic, and oxidized flavors in the experimental cheese. Moreover, it sometimes produced a bleached appearance and also a blue-gray cast and even blue spots in the cheese. Vats and other utensils made of stainless steel,

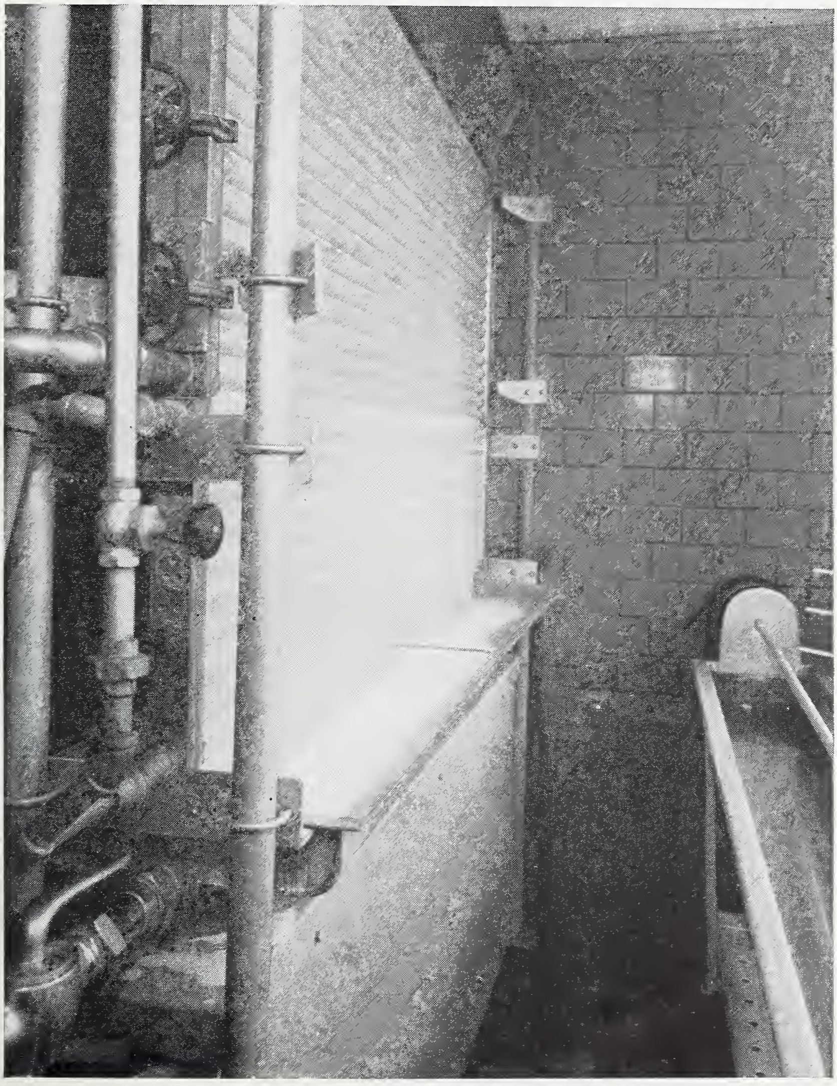

Figure 3.–Tubular, regenerative, high-temperature, short-time pasteurizer. The incoming cold milk is warmed as it flows inside the tubes toward the pasteurizing section, and the pasteurized hot milk is partly cooled as it flows over the inlet tubes.

and seamless cans properly tinned, are recommended.

In some factories the milk is filtered. Filtering has no sanitizing effect, but it is an additional safeguard against an excessive amount of extraneous matter in the cheese. The milk may be filtered before it reaches the pasteurizer, or the filter may be installed to filter the warm milk flowing from the regenerator into the heating section of the pasteurizer.

The plant and the equipment should be constructed of suitable material and so arranged that they can be kept clean with a minimum of effort. All the equipment with which the milk comes in contact should be clean and as nearly sterile as possible. This includes the strainer, weighing tank, receiving tank, separator parts, pasteurizer, filter, pipes, vats, thermometers, curd knives, rakes, forks, agitator paddles and forkers, and pails. It is especially important to clean and sterilize all the equipment with which the milk comes in contact after it is pasteurized.

All equipment and containers should be cleaned thoroughly and scalded after each use, then left to drain and dry in a clean, dust-free place. Just before they are used again they should be treated with a disinfecting solution, after which the solution should be drained off. A chlorine solution containing 200 p.p.m. of available chlorine is a suitable disinfectant.

Each morning, put all the utensils to be used that day in the cheese vat and put the disinfecting solution into the weighing and receiving tanks. Then pump the solution through the pipelines, filter, pasteurizer, and cooler into the vat and the whey drain pan. Also, sterilize the whey pipelines, pump, and whey tank, as well as the interior of the cans. Finally, drain off the solution completely.

Before pasteurization of the milk is actually begun, establish the correct pasteurizing temperature by using water instead of milk. First pump water from a supply tank through the pasteurizer and back to the tank. When the pasteurizing temperature has been correct for several minutes, turn off the flow of water and turn on the flow of milk from the receiving tank.

To obtain skim milk for standardizing the vat milk, it is a good practice to divert milk from the regenerative section of the pasteurizer to the separator. The skim milk flows from the separator into a small tank, from which it is pumped into the whole milk going to the pasteurizer.

The effectiveness of pasteurization can be determined by means of the phosphatase test. A phosphatase enzyme is present in all raw milk, and pasteurization inactivates it almost completely. More than a slight but definite amount of phosphatase activity, as determined in the test, indicates underpasteurization. The Bureau of Dairy Industry has developed a reliable and accurate phosphatase test for detecting underpasteurization in milk, cream, cheese, whey, and other dairy products (*31*).

The test should be run at least daily, preferably on each vat of milk or each lot of cheese. If the pasteurizing temperature fluctuates more than 1° F., or 2° at the most, the test should be run also on samples taken at frequent intervals from the pasteurizer outlet, until the fluctuation of the temperature has been corrected.

STARTERMAKING

Detailed descriptions of methods and equipment for propagating the lactic starter have been published by specialists in agricultural experiment stations (*25, 47*) and by some of the firms (*9, 12, 17*) that sell starters. No attempt will be made, therefore, to give a complete description here.

The introductory work done in factories by the Bureau's technologists revealed that poor quality in pasteurized-milk cheese was usually traceable directly to the use of defective starters. The most common defects were contamination and loss of activity. Because of the **absolute necessity of a uniformly active starter** for producing a correct and uniform rate and amount of acid development, the following essentials of good startermaking are emphasized.

Startermaking equipment

The startermaking equipment includes containers, pipettes, sterilizer, and incubator.

The containers for mother cultures may be pint bottles or 500-milliliter Pyrex Erlenmeyer flasks. In either instance, precautions must be taken to prevent contamination of the container's lip. The operator's fingers must not touch the lip. The mouth and lip of

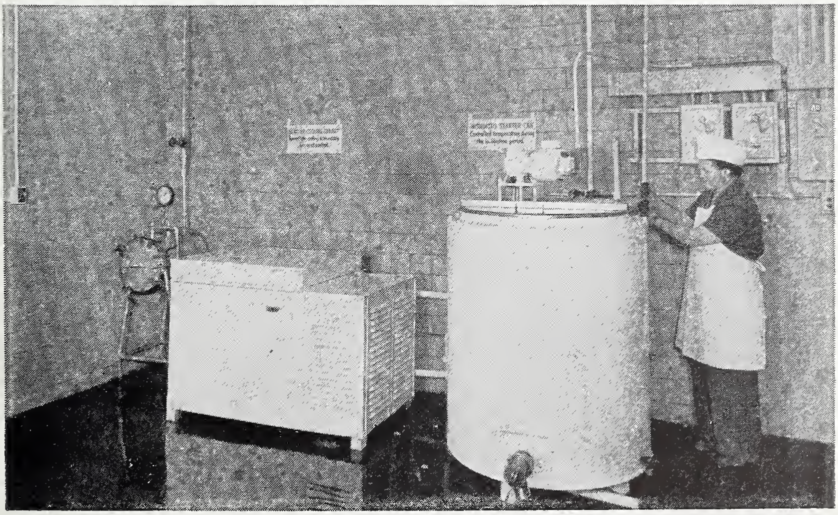

FIGURE 4.–Autoclave sterilizer (left) for mother-culture milk and pipettes, a refrigerator unit for cooling and holding cultures (center), and a modern starter can (right). The starter can has a steam connection for heating the milk, a cold-water connection for cooling, and an electrically operated stirrer.

the container must be covered. The cover may be parchment, which should be fastened down with a metal cap (*25*) or tied with string. Cotton stoppers may be used with Erlenmeyer flasks. After a stopper is inserted, the stopper and the neck of the flask should be covered. They may be covered with parchment, which should

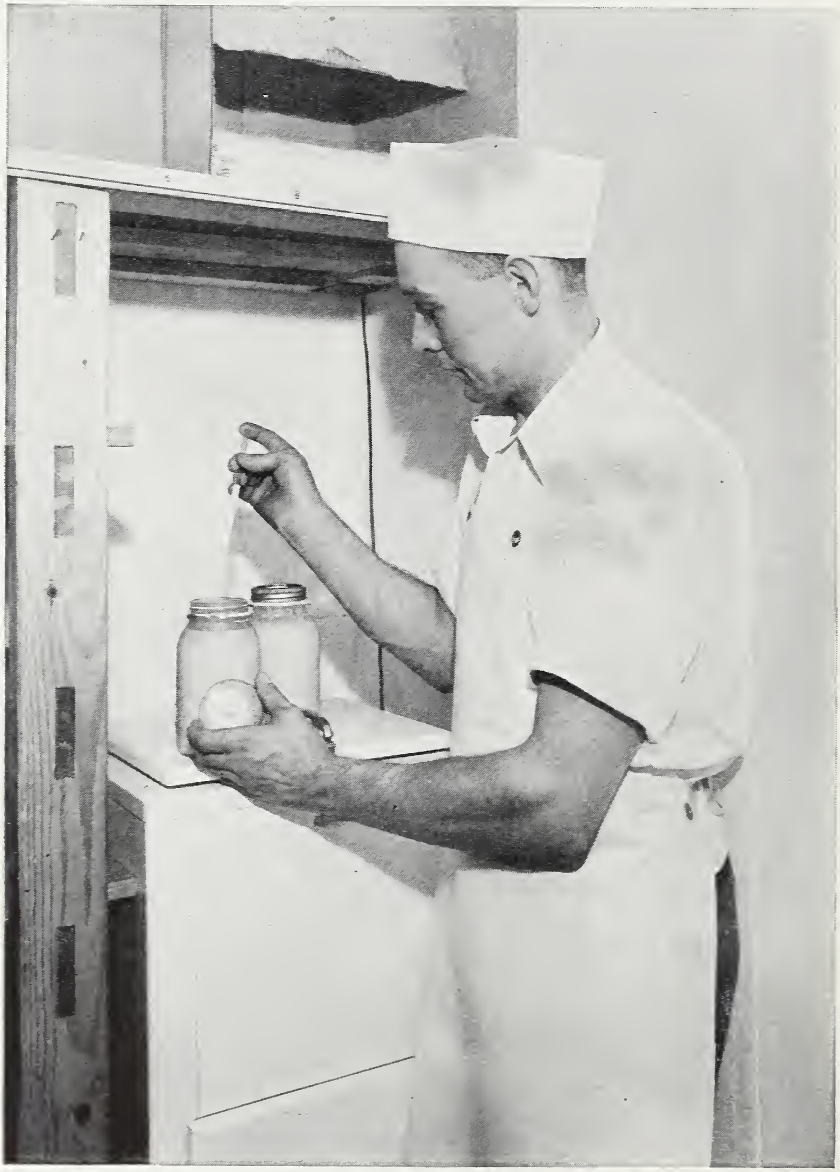

FIGURE 5.–Startermaker transferring the mother culture with a sterile pipette.

be fastened loosely around the neck with string; or they may be covered with a hood. To be sure that the plug will stay dry, the flask should not be filled more than half full.

The container for the bulk starter may be a large, insulated starter can; or 5- or 10-gallon stainless steel cans, which are placed in an insulated tank, may be used (fig. 4).

Pipettes of 1-milliliter capacity should be used for transferring the mother cultures. They must be clean and sterile and must be kept in a metal tube with a tight-fitting cover (fig. 5).

The sterilizer for mother-culture milk should be a steam-pressure sterilizer or autoclave. The pipettes can be sterilized in an autoclave, but it is desirable to have a hot-air oven-type sterilizer (preferably electric) in which they can be sterilized by heating at not less than 320° F. for an hour.

Some cheesemakers incubate the mother cultures by suspending the containers in the bulk-starter can or tank, but the use of a separate incubator or starter cabinet for the mother cultures reduces the chance of contamination.

It is most desirable, for convenience and also to avoid contamination, to have all the startermaking equipment, including cleaning facilities, in a laboratory room separate from the manufacturing room.

Quality of starter milk

Only the best milk obtainable should be used for making starter, especially for making the mother cultures. The starter milk should be obtained daily from a patron who delivers milk of the best quality. It should be from healthy cows and should be strictly fresh, sweet, clean, rich in solids-not-fat, and free of antibiotics (used in treating mastitis). Its methylene-blue reduction time should be not less than 6 hours.

A milk suitable for startermaking can also be prepared by reconstituting spray-dried non-fat milk solids (powdered skim milk) of excellent quality, as described by Horrall and his associates (*10*). Starter prepared with it was found to be active and uniform. To prepare the reconstituted milk, mix powdered skim milk in pure water at the rate of 5 pounds of powder to 45 pounds of water (10-percent solution), at a temperature of 80° to 85° F. Distilled water is recommended, but well water that has been tested and found not to inhibit starter growth is satisfactory. Add the powder to the water slowly while agitating the mixture, and agitate it until the powder has dissolved, which may take about 15 minutes. Then put it in the containers and sterilize it promptly.

Sterilizing the starter milk

Milk for the mother culture should be sterilized—not merely steamed—in order to kill all bacteria that otherwise might grow and spoil the culture. Half-pint portions of milk in 500-milliliter flasks or in pint bottles can be sterilized by heating in a steam-pressure autoclave for 15 minutes at 15 pounds' pressure. In some factories where an autoclave is not available, the mother-culture milk is heated in flowing steam for at least an hour. However, this method is not reliable; it does not accomplish sterilization.

Effective sterilization should produce only a slightly tan color in milk. A distinctly brown color indicates that the period of sterilization was too long, or the temperature was too high. Overheating makes the medium less suitable for active growth of the starter bacteria.

Milk for the bulk starter does not need to be actually sterilized. However, it must be heated sufficiently to kill almost all of the micro-organisms. It usually is heated at not less than 185° F.—preferably at or near 200°—for 1 hour, with frequent stirring. It is then cooled to 70°.

Preventing contamination

Contamination of the starter—especially the mother culture—must be avoided; contamination with foreign micro-organisms causes loss of activity and injures the quality of the starter. Contaminating micro-organisms may be carried in dusty or vapor-laden air, in a starter medium that is not sterilized adequately, and on nonsterile equipment such as pipettes and the lips of flasks.

It is safer to use a sterile pipette for transferring the culture than to pour it from a flask. The sterilized pipettes should be removed from the pipette containers only one at a time and only at the time of inoculation. The pipette should be held in the hand and not laid on the table. The tip end must not be allowed to touch any nonsterile object. Likewise, the openings of the bottles or flasks containing culture or sterile milk should not be exposed to air or to contamination by dust any longer than necessary for the inoculation. Thermometers or nonsterile pipettes must not be placed in the sterile milk or culture. The daily transfer of the mother cultures should be made before rather than after they are titrated for acidity, in order to reduce the risk of contamination.

It is good practice always to carry three or more mother cultures, so that if one becomes contaminated or inactive another can be selected for use.

Incubation temperature

A correct temperature for incubation of both the mother culture and the bulk starter is 70° F. The sterile mother-culture milk and the bulk-starter milk should be cooled to that temperature before inoculation. The temperature in the incubator, and also in the bulk-starter can or tank, should be controlled automatically with a heating unit (placed in the bottom) and a thermostat.

Uniformity of procedure

Strict uniformity in all the steps in startermaking from day to day is very important in maintaining a uniformly active starter.

This requires the following: A constant incubation temperature; a standard incubation period, that is, setting the starter at the same time each day and removing and cooling it at the same time and to the same temperature; using the same quantity of inoculum (as a rule, 2 drops in ½ pint for mother culture and 4 ounces in 10 gallons for bulk starter); and daily titrations of both the mother cultures and the bulk starter, with titratable acidity always between 0.7 and 0.8 percent when ready to use.

To obtain uniformity, it is the best practice to assign to one person the job and responsibility of making the starter.

Factory operators say that introduction of the time-schedule method of cheesemaking has tended to take the art out of cheesemaking and place it in startermaking. This emphasizes the importance of an active and uniform starter.

THE TIME-SCHEDULE METHOD

A time schedule for manufacturing Cheddar cheese from pasteurized milk (fig. 6) was developed by the Bureau of Dairy Industry and is being used in many factories with excellent results. Unlike the more general time schedules proposed earlier by Sammis and Bruhn (*30*) and by Price (*22, 23*), it specifies a definite time for each step in the making process. Price (*24*) has recently described a time-schedule method which is much more specific than his earlier method and in which the making schedule is very similar to that described here.

The use of a definite schedule for each step is possible because pasteurization makes different lots of milk, of different qualities, relatively uniform.

DEVELOPMENT OF ACIDITY

If the quality of the milk is good and if the cheese is cured properly, the **amount** of acid that develops and the **rate** of its development during the making process have more influence than any other factors on the quality of the cheese. The acidity produced by a given quantity of starter develops generally more rapidly in good pasteurized milk than in good raw milk, and therefore less starter is needed when the milk is pasteurized.

The time schedule was developed experimentally to produce the correct acidity at each stage in the making process for manufacturing cheese of the best quality from pasteurized milk. Acidity is controlled by adding only enough starter to the milk so that the whey draining from the curd 4½ hours after setting will contain 0.5 percent of acid (or 0.6 to 0.7 percent 5½ hours after setting). The cheesemaker is cautioned against an excessive rate and amount of acid development caused by using too much starter, which produces acid and bitter flavors and also short and often pasty body in the cheese.

It is much easier to control the development of acidity uniformly during the making process if the temperatures indicated in the time schedule are followed.

If this method is followed closely, the development of acidity will be normal and the cheese will be free, or practically free, of acid flavors and bitterness. In addition, it will have a firm, curdy body, from which a plug sample will be smooth, when it is 2 or 3 weeks old; and it will be reasonably free of mechanical openings. When it is 2 months old or older, the cheese will have a firm,

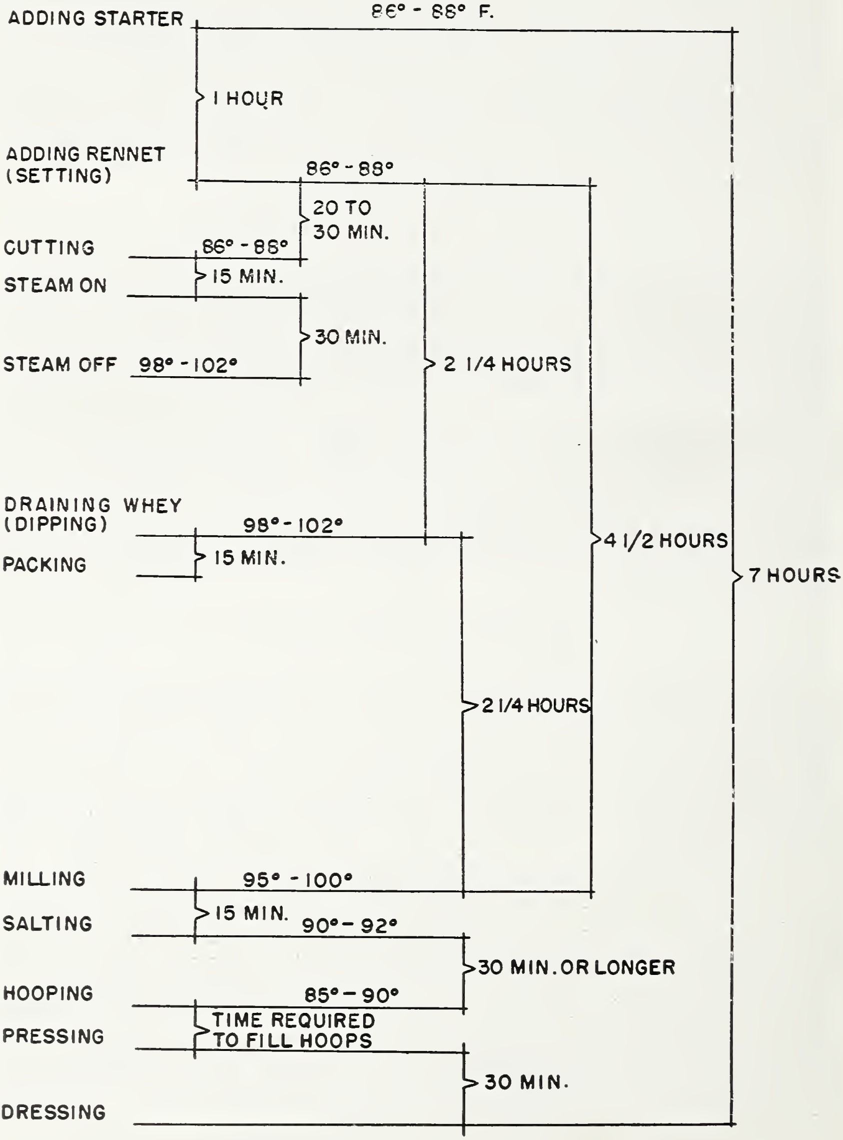

FIGURE 6.–Time schedule for making American Cheddar cheese from pasteurized milk (4½-hour method).

smooth, waxy body and will be reasonably free of mechanical openings; it will generally be free of unclean flavors; and it will retain these properties until cured if it is held under favorable conditions in curing and storage.

Cheese that is drier and firmer and that has a slightly more pronounced flavor and better keeping quality can be made by using a longer time schedule (referred to as the 5½-hour method), which takes 5½ instead of 4½ hours from setting (adding the rennet) to milling. The only difference between the two schedules is that the longer schedule requires 3¼ hours instead of 2¼ hours from dipping to milling, or a total making time of 8 hours instead of 7 hours from the time of adding the starter until the time of dressing the cheese. The only disadvantage of the longer method is the extra time involved.

USING THE CLOCK TO SYSTEMATIZE CHEESEMAKING

The time-schedule method, with a dummy clock above each vat, makes it possible to organize and simplify the work in factories having several vats (fig. 7). The vat clock consists of a sheet-metal face, about 10 inches in diameter, on which clock numerals are superimposed or printed and on which clock hands are mounted so that they can be rotated manually. The operator follows the time schedule by observing a wall clock showing the actual time, and he records the actual time when each step is begun. In addition, at the beginning of each step throughout the

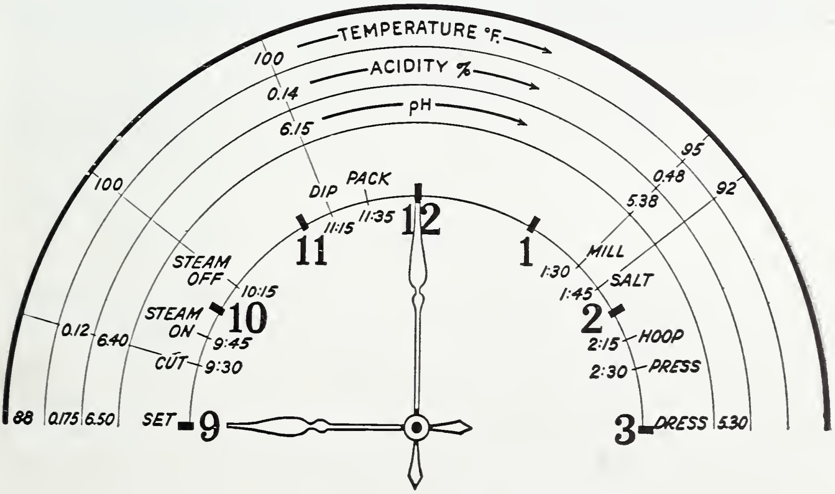

FIGURE 7.–Clock diagram of the pasteurized-milk, time-schedule method of making American Cheddar cheese developed by the Bureau of Dairy Industry. Here the milk is being set at 9 o'clock, at which time the hands of the vat clock are set ahead to 9:30, when the curd is to be cut.

making process, he moves the hands of the vat clock ahead to the actual time when the next step is to begin.

For example, when the starter is added, the actual time is recorded and the hands of the vat clock are set ahead to the actual time when the milk is to be set with rennet. Then, when each succeeding step is begun, the time is recorded and the hands are set ahead to the time when the next step is to begin.

Use of a clock for each vat makes it possible for the cheesemaker to avoid errors in supervising accurately the work being done in each vat. It saves the operators many steps and does away with the necessity of constantly referring to records or relying on memory. In large factories especially, it is a means of systematizing the cheesemaking, saving time of the cheesemaker and helpers, and avoiding errors in following the schedule.

Use of a continuous pasteurizer makes it possible to set the vats at regular intervals. Thus, the individual steps can be staggered, and one person can carry out one or more particular parts of the work in each of several vats. Obviously, persons assigned to specific steps in the process every day become more efficient and do the job better with less supervision. Moreover, in large factories using this system, time is saved by having some employees report for work at different times during the day.

MANUFACTURING PROCEDURE

PASTEURIZING THE MILK

A high-temperature, short-time method of pasteurization—heating the milk to 161.5° to 162° F. and holding the temperature as nearly constant as possible for 15 seconds—is recommended. The temperature should **never exceed 165°**, and preferably never 163°. The cooler should be so adjusted that the milk will be cooled only to the setting temperature of 86° to 88°, to avoid reheating before setting. This is also a satisfactory temperature at which to add the starter.

ADDING THE STARTER

To develop the desired amount of acidity during the making process, add enough starter to the milk (fig. 8) and adjust the length of the ripening period to produce approximately 0.5 percent of acid in the whey draining from the curd 4½ hours after setting. With a ripening period of 1 hour, this usually will require only 0.5 to 1 percent of starter. If more starter is required, the cause of the difficulty should be determined at once and corrected. It may be due to poor quality of either the starter or the milk, to unusual contamination of the milk after pasteurization, to inadequate control of the temperature during the making process, or possibly to the presence of an antibiotic (used in treating mastitis) in the milk.

ADDING THE RENNET (SETTING)

Add the rennet 1 hour after adding the starter. If cheese color is used, add it also at this time.

Before adding the rennet, adjust the milk to a definite temperature, the same every day, within the range of 86° to 88° F. A setting temperature of 88° is recommended.

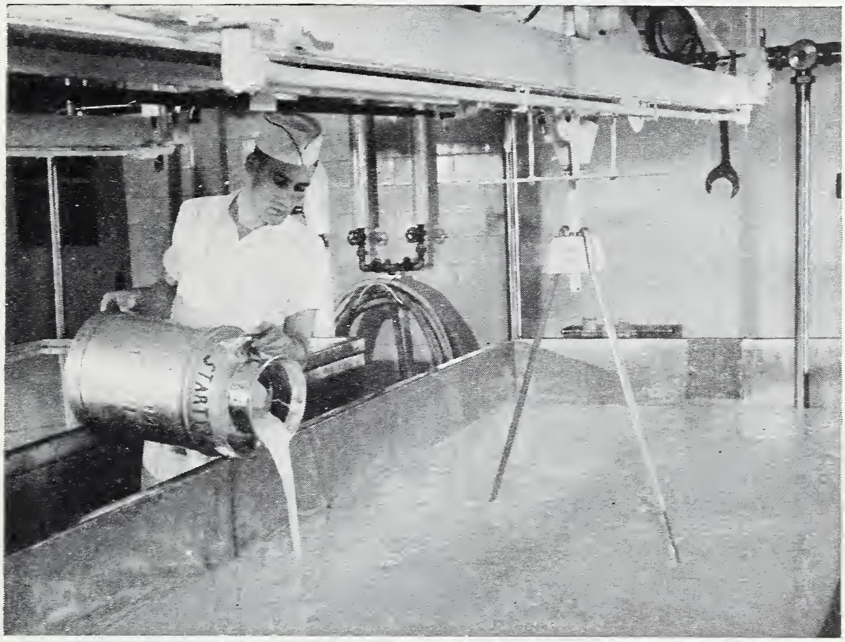

FIGURE 8.–Adding the starter. The milk is flowing in through the pipe in the end of the vat. The mechanical agitator rotates and moves from end to end of the vat.

Add 3 ounces of rennet extract (which has been diluted with 40 times its volume of water) for each 1,000 pounds of milk, distributing it the entire length of the vat, and stir it in thoroughly (fig. 9). Never use less than 3 ounces of rennet for each 1,000 pounds of milk—usually 3 ounces will be enough. Under normal conditions this quantity will produce curd of the correct firmness for cutting in 30 minutes, depending on the acidity and temperature of the milk.

After the color and rennet are mixed in, drain out the milk that is in the vat gate (outlet valve) and mix it with the milk in the vat. Then stop the agitator and remove the paddles.

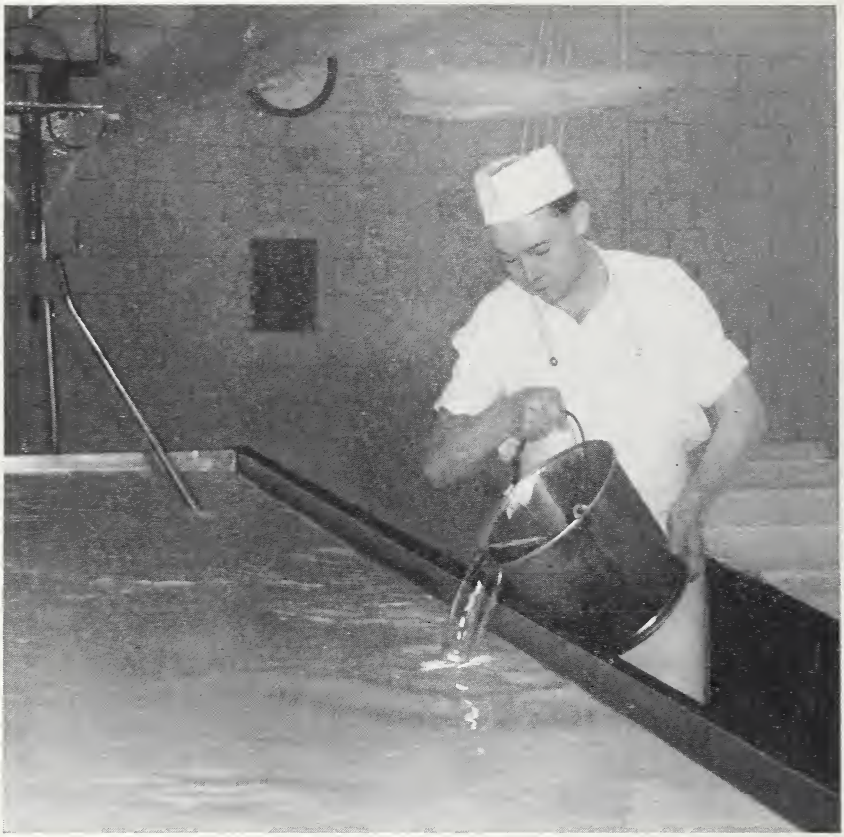

FIGURE 9.–Adding the diluted rennet extract. It is distributed over the entire length of the vat and stirred in thoroughly. Then the agitator is stopped and the paddles are removed.

CUTTING THE CURD

The curd should be firm enough to cut 30 minutes after setting. To test the curd, insert a blunt instrument into the curd and raise it slowly, as shown in figure 10. If the curd splits evenly ahead of the instrument, it is ready to cut.

Cut the curd into even and uniform cubes with curd knives having either ¼-inch or ⅜-inch spaces between the wires, but preferably ¼-inch (fig. 11). The smaller cubes drain and firm faster than ⅜-inch cubes and usually will make a drier cheese. At the time of cutting, the acidity of the whey should be between 0.11 and 0.13 percent, depending on the acidity of the milk before it was pasteurized.

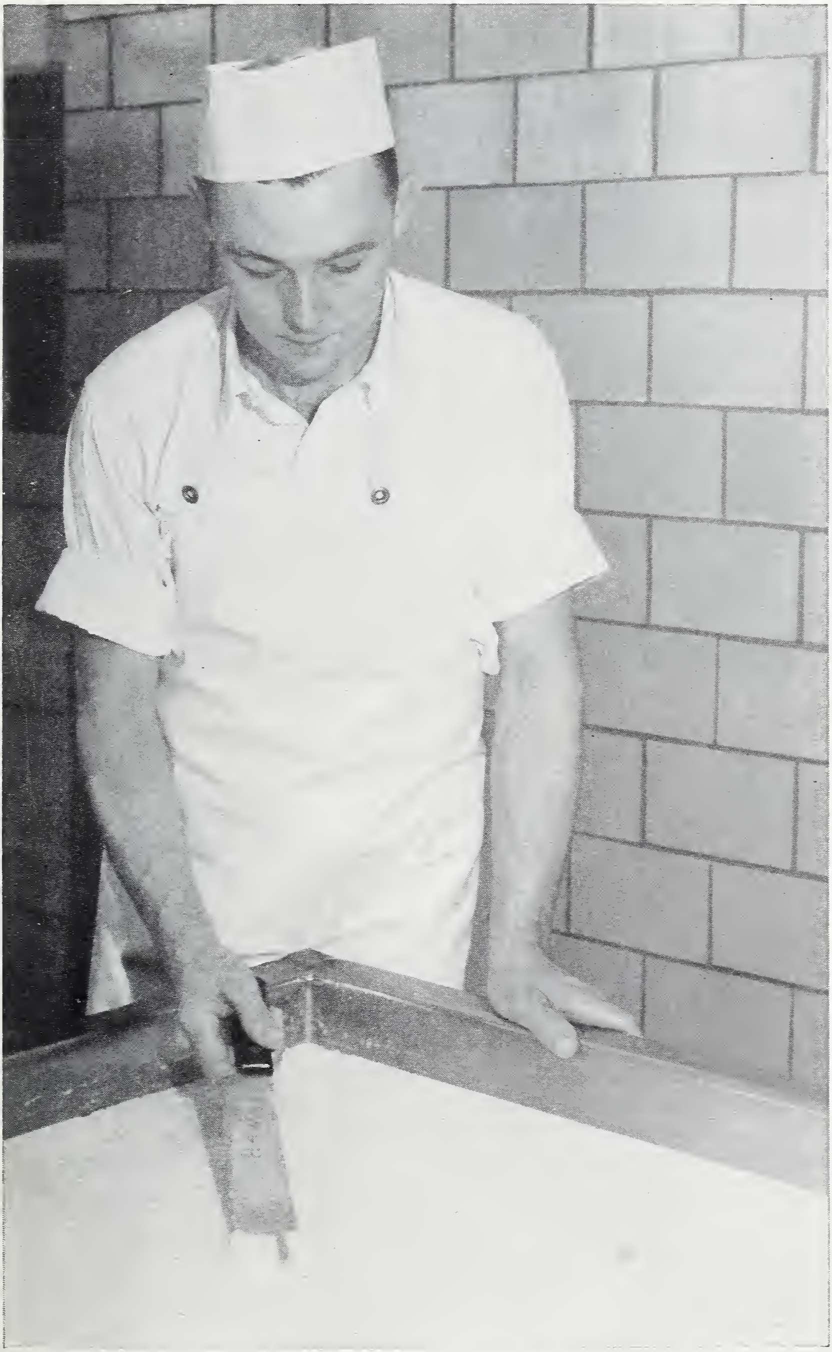

FIGURE 10.–Testing the curd. When it splits evenly ahead of a blunt instrument that is inserted and raised slowly, it is ready to cut.

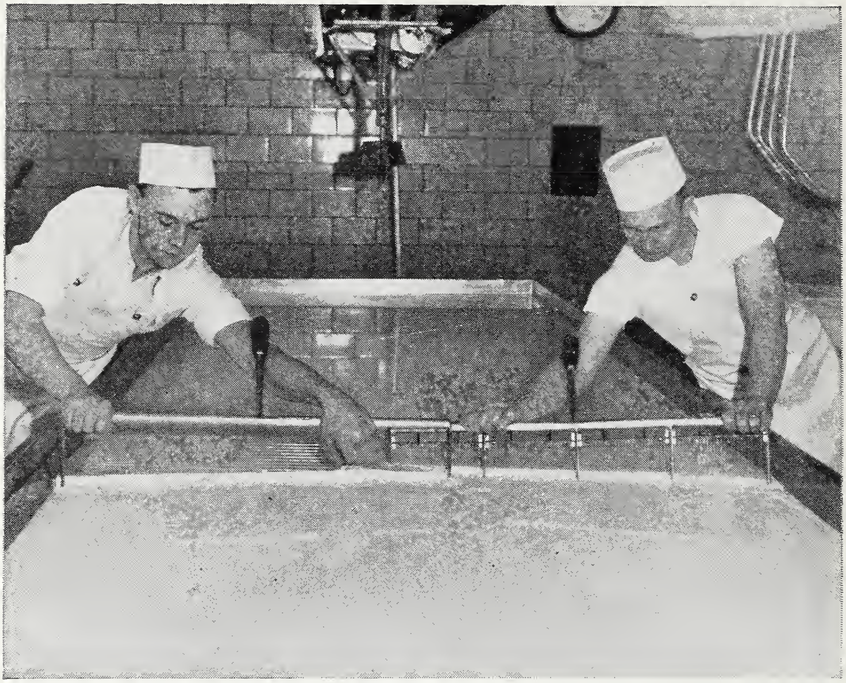

FIGURE 11.–Cutting the curd. The knives are taut wires stretched at ¼- or ⅜-inch intervals between metal frames. The knife at the right cuts the curd vertically; the one at the left cuts it horizontally. When the operators have pulled the knives from one end of the vat to the other, they will exchange knives and pull them back to the starting end. Then they will cut the curd crosswise with the vertical knife. This cuts the curd into ¼- or ⅜-inch cubes.

HEATING OR COOKING THE CURD

Stir the curd continuously, with the mechanical agitator or a rake, from cutting to dipping. To firm the curd, begin heating it 15 minutes after cutting it. Careful attention to the heating is necessary in firming the curd (fig. 12). Curd that is not firmed gradually and to the right extent in the whey will make cheese having a weak, pasty body and usually an acid or sour flavor. Heat the curd slowly for the first 10 or 15 minutes. Bring the final temperature gradually (not rapidly) to within a range of 98° to 102° F. (preferably 100°) in 30 minutes (never less than 30 minutes). Stir the curd slowly and continuously during heating to insure uniform heat treatment and to avoid matting or clumping. Do not heat the curd any higher than is necessary to firm it properly. Higher temperatures will retard to some extent the growth of the starter bacteria and therefore will retard the development of acidity.

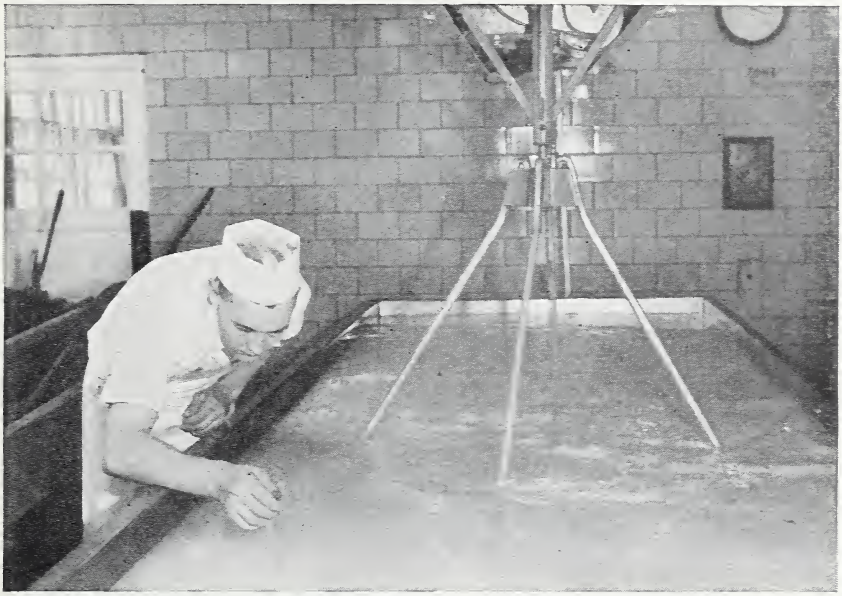

FIGURE 12.–Heating the curd. The steam has been turned on in the jacket, and the cheesemaker determines the temperature while the agitator gently stirs the curd.

DIPPING (DRAINING THE WHEY)

Push the curd back from the gate end of the vat and start draining the whey $2\frac{1}{4}$ hours after setting. **Titrate the acidity of the whey at this time** (fig. 13). It should be from 0.13 to 0.15 percent (depending on the acidity of the milk before it was pasteurized), or usually about 0.02 percent higher than it was at the time of cutting the curd.

When pumping facilities are inadequate for removing all the whey in less than 15 minutes, remove part of it shortly before the scheduled time for dipping, and then operate the agitator again until dipping.

DITCHING AND PACKING THE CURD

When drainage of the whey has been nearly completed, make a ditch lengthwise down the middle of the vat, trim the rough edges of the curd, and place all loose particles on top of the curd (fig. 14).

Pack the curd about 7 or 8 inches deep. If the vat was full of milk at the start, there may be so much curd that it will be necessary to pack it over almost the entire bottom of the vat, leaving only enough room to permit drainage and convenient turning and handling.

Immediately after the curd has been packed neatly, titrate

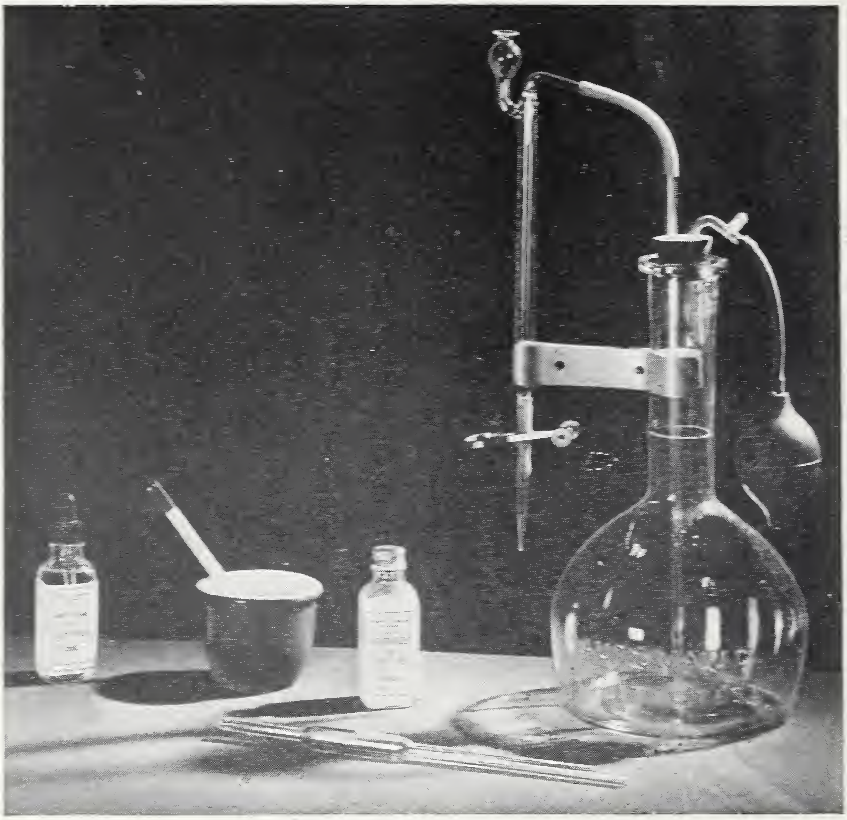

FIGURE 13.—Acidity tester for titrating the acidity of the milk, whey, and starters, showing the flask for tenth-normal alkali, with automatic burette, a 9-milliliter pipette, a neutralizer for preparing the alkali solution, a cup and stirring rod, and a phenolphthalein indicator.

the acidity of the whey draining from it. The acidity should be from 0.17 to 0.22 percent, but may vary from 0.16 to 0.25 percent. The higher acidity values should be avoided when making high-moisture cheese (37 to 39 percent).

CHEDDARING OR MATTING THE CURD

The objects of cheddaring or matting the curd are to expel whey, to develop acid in the curd, and to produce a smooth, silky curd that will have a meaty texture resembling in appearance the cooked white meat from a chicken's breast and that when cut will appear reasonably free of mechanical openings. The piling should be done slowly. If it is done too rapidly, too much whey will be retained in the curd, acid will develop too rapidly, and the curd will be too soft. This will result in a cheese having a weak and pasty body. On the other hand, curd that has been firmed sufficiently in the whey and cheddared and piled slowly will make a firm-bodied, high-grade cheese.

During the entire cheddaring or matting process, until the curd is milled, keep the temperature of the curd near 100° F.; never let it go below 95° or above 100°.

(1) As soon as the curd has matted sufficiently to be turned without breaking, cut it into slabs 5 or 6 inches wide and give each slab a one-half turn. Keep the slabs tight against the side of the vat and against each other.

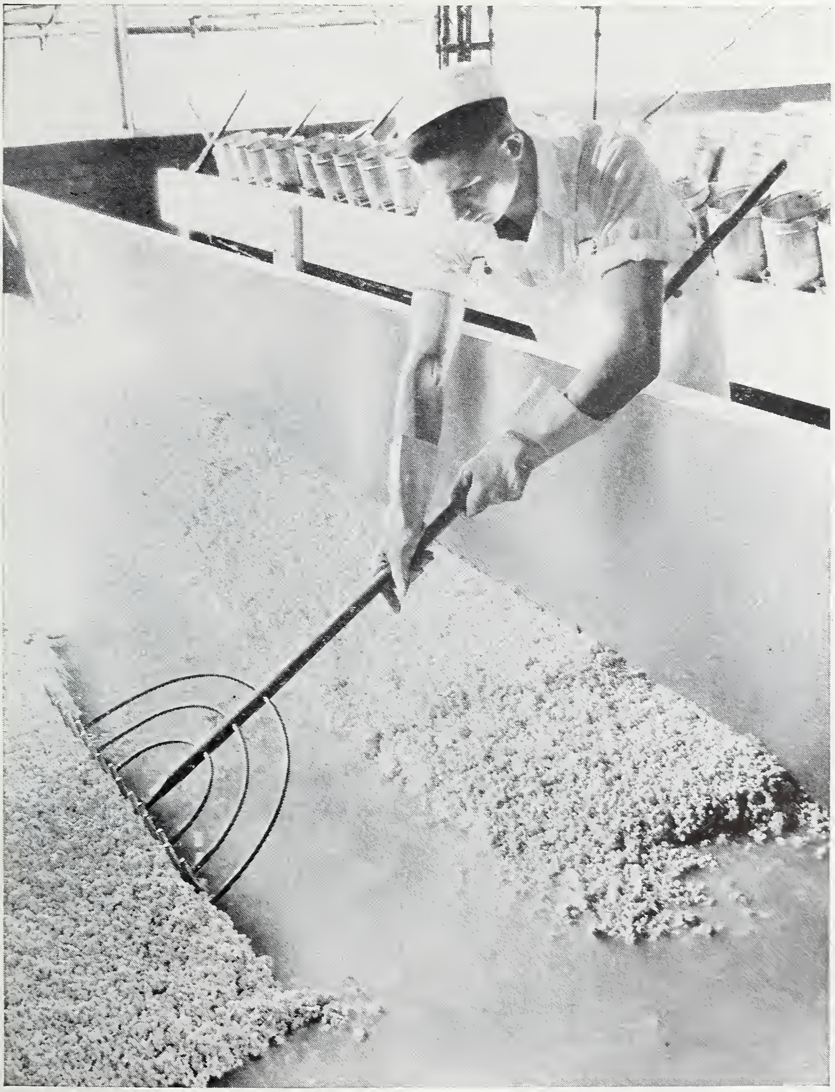

FIGURE 14.–Ditching the curd. This step follows draining of the whey.

(2) After 10 minutes, slide (but do not turn) each slab about 6 inches to permit the whey to drain off and to aid in smoothing the rough side of the slabs.

(3) After another 10 minutes, give each slab a one-fourth turn.

(4) After another 10 or 15 minutes, give each slab a one-half turn.

(5) After another 10 or 15 minutes, give each slab a one-fourth turn, which will place the rough side down. During the first hour, while the curd is warm and tender, the slabs should be turned every 10 or 15 minutes. This will make all sides smooth and will prevent some of the mechanical openings in the cheese.

(6) After another 10 or 15 minutes, give each slab a one-half turn. The curd should be quite firm by this time, and the slabs may be cut in two and doubled over, giving both slabs a one-half turn and piling them in two layers, as shown in figure 15. If the curd is not firm enough and has not begun to feel dry, piling may be delayed until the next turning.

(7) Continue to separate and repile the slabs in two or more layers every 10 or 15 minutes until the curd is milled. Reverse the ends occasionally, and put the rougher slabs at or near the bottom. Always keep the vat covered between these operations and, when necessary to keep the curd from cooling too rapidly,

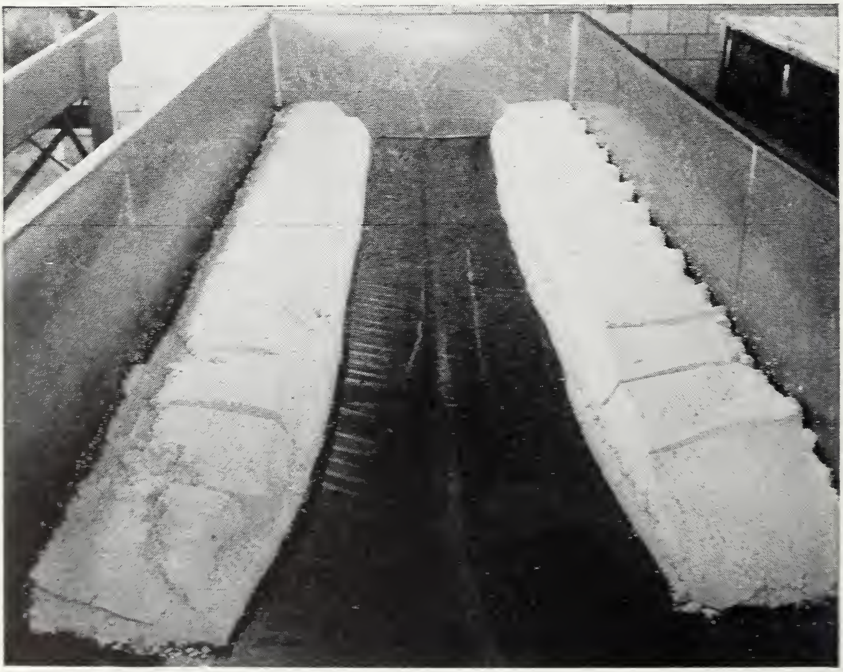

FIGURE 15.–Cheddaring the curd. It has become quite firm at this stage. Each slab is cut in two, and the piece toward the center of the vat is turned back over the other half.

admit enough steam into the jacket of the vat each time the slabs are turned to keep the bottom of the vat warm. If the room is cold the curd may cool too rapidly, and it will be necessary to take special precautions to keep the temperature of the curd from falling below 95° F. If the temperature of the curd is lower than 95° at milling, the cheese may have openings in the rind when it is removed from the press.

(8) During the last 45 minutes of cheddaring or matting the curd, it may be desirable to pile the slabs in more than two layers, depending on the firmness of the curd. If the curd is sufficiently firm, the slabs can be piled in three or four layers, or even more; but if the curd is not so firm as desired, piling it in only two layers is preferable. Curd that flattens out rapidly after it is piled is too weak and will make a weak-bodied, pasty cheese that will not cure properly and will not retain its shape in storage. Curd that will stand piling and that becomes smooth and silky and at the same time retains its firmness and holds its shape will make a firm-bodied cheese that can be held satisfactorily under storage conditions. If it is desired to make high-moisture cheese, the slabs may be piled sooner and in more layers. On the other hand, if lower-moisture cheese is desired, piling should be delayed and the cheese should be piled in fewer layers.

Titrating the acidity of the whey

Four and one-half hours after adding the rennet (or 2¼ hours after dipping), take a sample of the whey draining from the curd and titrate it to determine its acidity. At this time the acidity should be within a range of 0.45 to 0.50 percent, and **the curd may be milled**. The acidity may be as low as 0.40 percent if the milk is of exceptionally good quality. The acidity may be slightly higher than 0.50 percent—up to 0.55—in making low-moisture cheese, but 0.50 percent or slightly lower is preferable in making high-moisture cheese.

If the acidity at milling is as low as 0.40 percent, there is a possibility that the cheese may develop fermented and fruity flavors. Also, research in the Bureau of Dairy Industry[8] has shown that with such low acidity at milling the cheese may ripen abnormally or it may ripen slowly (that is, there may be slow Cheddar-flavor development and extended curdiness in the cheese).

If cheese with **more flavor** and **better keeping quality** is desired, continue turning the slabs and cheddaring or matting the curd for **1 hour longer.** This will make the milling 5½ hours after the setting time, or 3¼ hours after the dipping time. In this 5½-hour method, the acidity of the whey at milling should be 0.6 to 0.7 percent.

Milling the curd

The temperature of the curd at milling should be between 95° and 100° F. Run the curd through the curd mill (fig. 16) and spread it evenly over the bottom of the vat. If the room is warm, operate the forkers or stir the curd by hand so that it will not clump or mat. Unless the room is too cold, avoid turning steam into the jacket of the vat after milling. Although slight heating after milling helps to expel whey, too much heat will cause leakage of fat, which will lower the yield and injure the quality of the cheese. Separation of fat from the curd at this stage is a frequent cause of checking (defective splitting) of the rind, which always results in a penalty in grade.

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[8] Unpublished data.

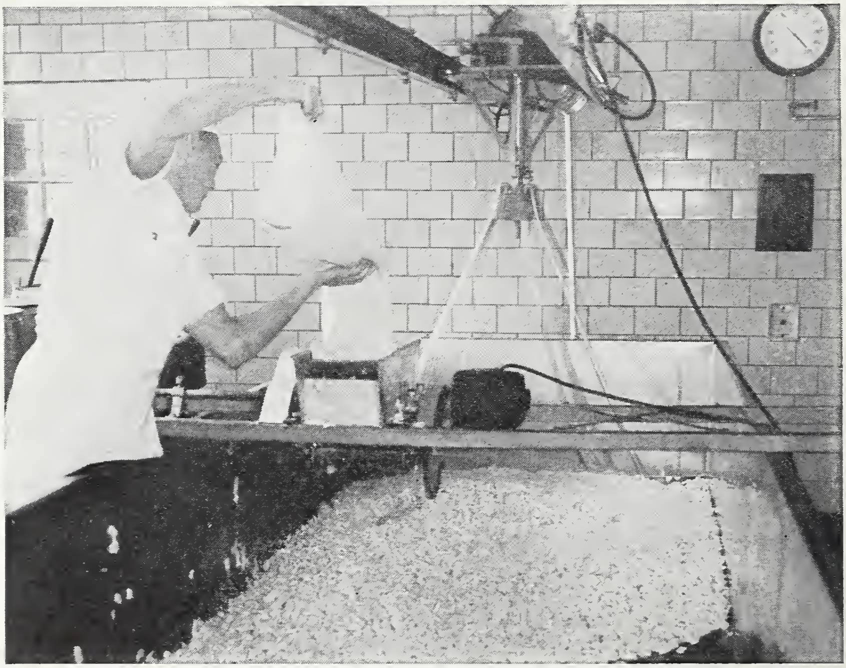

Figure 16.–Milling the curd. The milling machine, operated by an electric motor, cuts the slabs of curd into small pieces.

Salting the curd

Continue to stir the curd; then 15 minutes after the beginning of milling, start salting it. The temperature of the curd at salting should not be lower than 90° F. Add the salt slowly, in three applications, usually at the rate of from 2½ to 3½ pounds for each 1,000 pounds of milk (fig. 17). Use regular flake cheese salt, which will adhere to the curd until it is dissolved.

Fork the curd until the salt is distributed evenly. Then the curd can be piled on either or both sides of the vat to allow the whey to drain. When the whey has stopped draining, fork the curd again. Repeating this process several times will aid in producing cheese of fine quality. Such cheese will have a firm, curdy body (from which a plug sample will be smooth) when it is about

2 weeks of age, and will have a firm, waxy body and a texture reasonably free of mechanical openings when it is cured.

HOOPING THE CURD

Hoop the curd when the salt has dissolved completely and when the curd is as smooth and velvety as it was before salting. Do not hoop it before it has reached this condition. It usually requires from 15 to 30 minutes after salting for the curd to reach this condition, depending on the acidity and moisture content of the curd. If the room is warm, the texture and mellowness of the curd may be improved by allowing it to remain an hour after salting before hooping it, meanwhile forking it occasionally to prevent clumping.

The temperature of the curd at the time of hooping should not be lower than 85° F.; and when small styles of cheese, which cool rapidly, are being made, the temperature should not be lower than 88°. If the room is cold, it may be necessary to hoop the

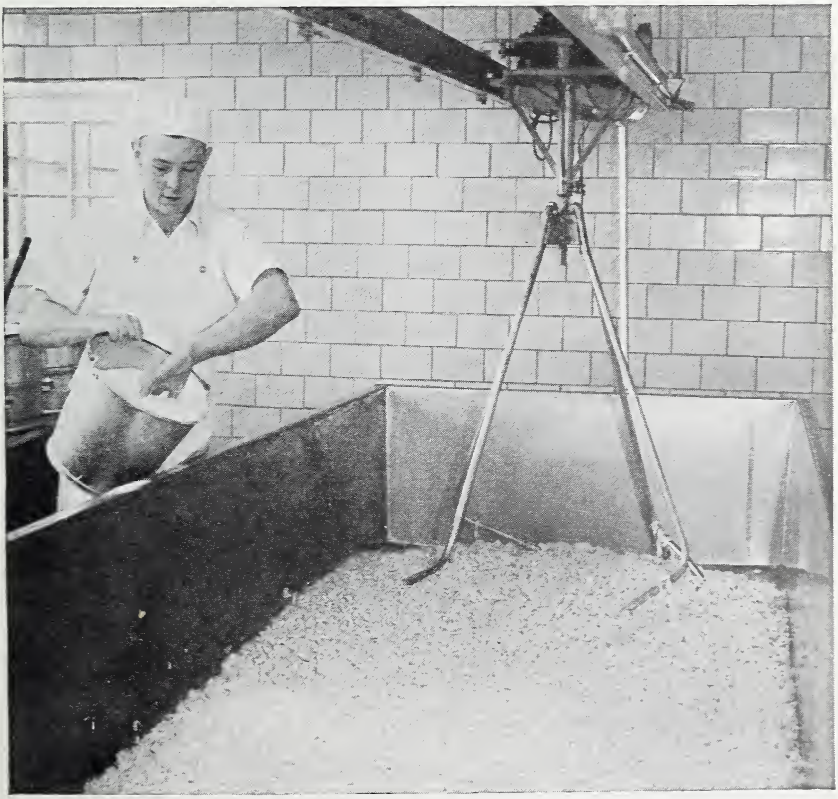

FIGURE 17.–Salting the curd. The cheesemaker sprinkles salt on the curd while the mechanical agitator, with special fork blades, stirs it slowly. The salt helps to remove whey and improves the flavor of the cheese.

curd at a temperature higher than 85° in order to compress the curd sufficiently in the press to form a rind that will be sound and free of the slightest openings. Also, the development of acidity is retarded if the temperature of the curd at hooping is too low.

Place a cap cloth and a starched circle in the bottom of each hoop, and be sure that they are free of wrinkles. Place a cheesecloth covering (bandage) in each hoop carefully, so that it extends to the bottom of the hoop and laps inward evenly from 1 to 1½ inches, and so that the seam is straight up and down.

Weigh the same amount of curd into each hoop, so that all the cheeses will be uniform in weight (fig. 18). If natural rindless

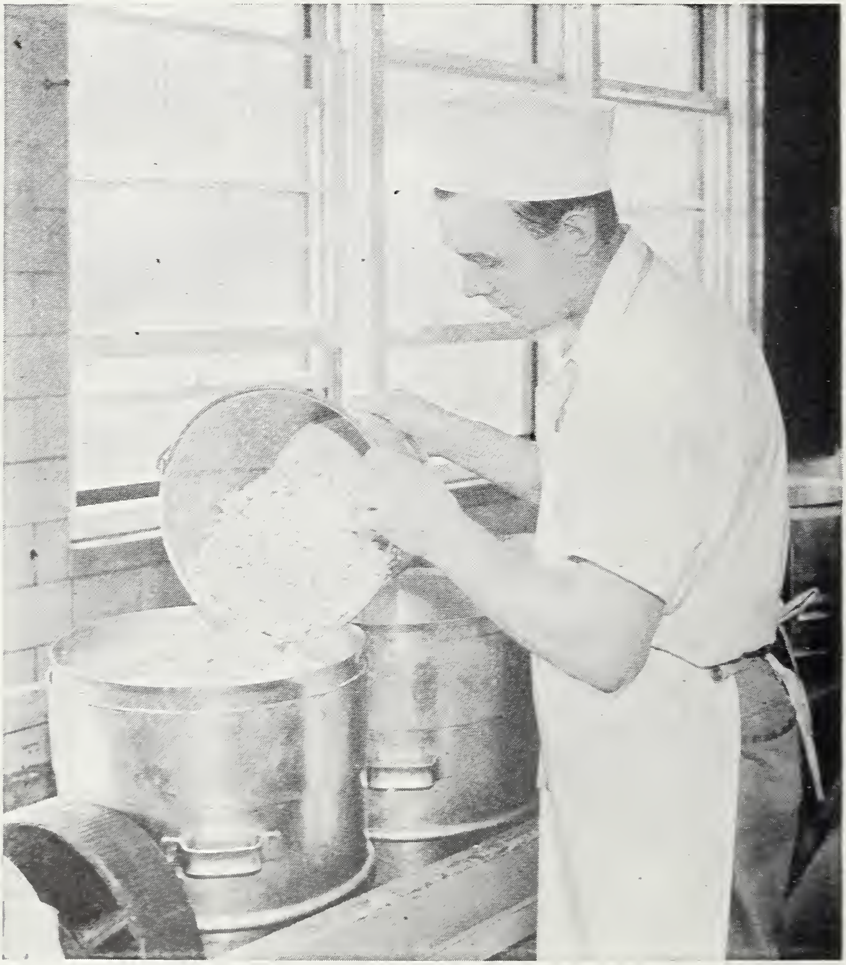

FIGURE 18.–Hooping the curd. As soon as the salt has dissolved completely, the curd is placed in metal hoops or forms, which have been lined with a cheesecloth covering (bandage).

loaf cheese is being made, the curd is placed in rectangular forms instead of circular hoops.

PRESSING THE CURD

Place the filled hoops in the press and apply pressure slowly to avoid loss of fat. Press them for not less than 30 minutes; then remove the hoops from the press and dress the cheese.

DRESSING THE CHEESE

Remove the bandagers (hoop rings), and pull up the bandages to remove all wrinkles. The bandage should lap 1 to 1½ inches over the top of the cheese after it has been pulled up. Place a starched circle next to the surface of the cheese and put a cap cloth on top of the starched circle. Then put the follower in place, and the cheese is ready for final pressing.

After the hoops of cheese have been put back in the press, rinse them off with warm water. This warms the surface of the cheese, which aids in closing the rind.

REMOVING THE CHEESE FROM THE PRESS

The cheeses should not be removed from the press and taken

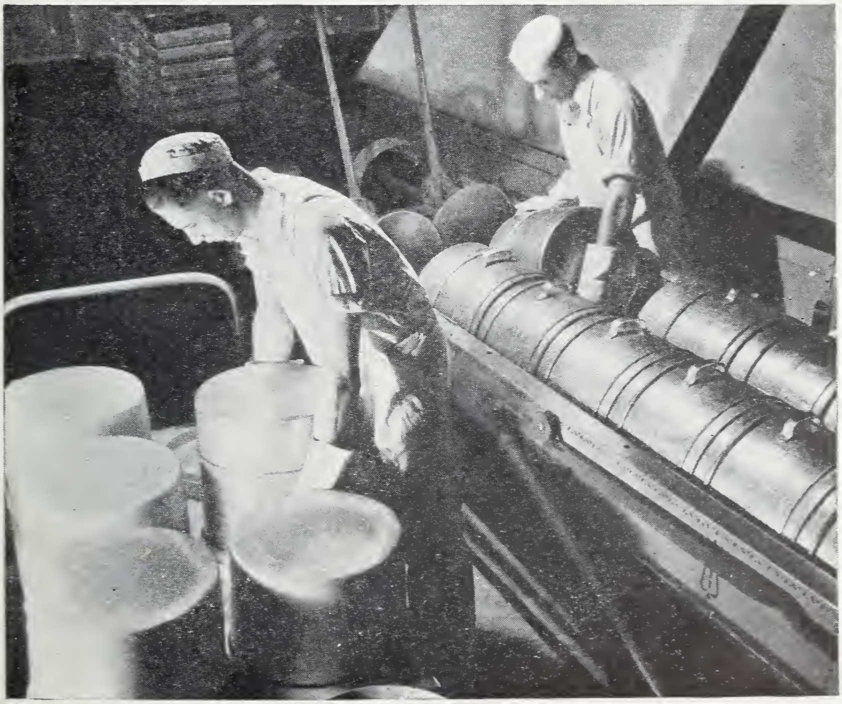

FIGURE 19.–Removing pressed cheese from the press and from the hoops and placing them on a truck to be taken to the drying room.

out of the hoops (fig. 19) until the rind is free of the slightest openings and all surface defects. This usually requires from 12 to 24 hours. Every bandage must be even at both ends, straight and free of wrinkles; and any cheese that is lopsided should be re-pressed.

Stamp the cheese for identification at this time—with the factory number, vat number, and date made.

After the cheeses have been removed from the hoops, wash the hoops thoroughly, rinse them, and put them in a clean place.

DRYING THE CHEESE

Remove the cap cloths before taking the cheeses to the drying room. Do not remove the starched circles; they help to prevent rind defects, including checking and cracking.

Place the cheeses on clean, dry shelves in the drying room and turn them once a day. If there is a shortage of shelf space, turn them twice a day to hasten drying. Leave them on the shelves until the rind becomes dry on both the top and the bottom of each cheese. At the end of the drying period—usually 3 to 4 days, depending on the moisture content of the cheese and the humidity of the drying room—all surfaces of the cheeses should be dry, clean, and free of mold, and they can be paraffined.

The temperature of the drying room should be between 50° and 60° F. so that the surface of the cheese will be in a condition suitable for paraffining. If the temperature is too low, the cheeses may sweat when they are exposed to warm air; if the temperature is too high, they may become greasy.

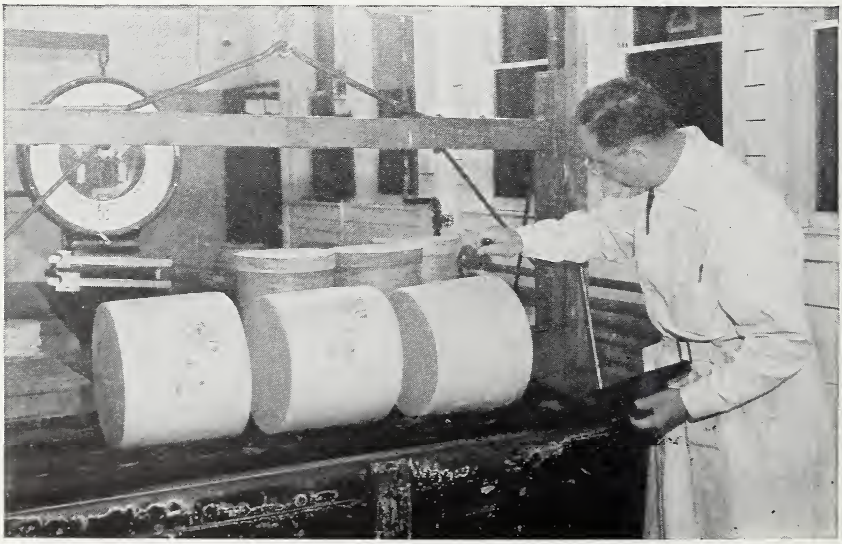

FIGURE 20.–Stamping and paraffining the cheese. A licensed grader stamps the cheeses with a grade. They are then dipped in hot paraffin, which forms an air-tight, mold-reducing covering.

PARAFFINING THE CHEESE

The cheeses usually are graded for the first time just before they are dipped in paraffin (fig. 20). They may be graded at other times, too (see p. 34).

Dip the cheeses in paraffin (or cheese wax) that has been heated to 220° F. It is important to have the paraffin hot; otherwise it forms a thick coating that will scale off. The rinds should be dry when the cheeses are dipped, because wet spots will develop blisters. If the cheeses are clean and dry and are paraffined properly, they will have a clean, shiny appearance.

BOXING THE CHEESE

After the cheeses have been paraffined, they usually are boxed —one to four in a box. The boxes must be clean and free of sawdust. The cheeses should be weighed at the time they are boxed. They should be uniform in weight and should fill the box completely. At least one scale board should be placed between the cheeses and also in the top and in the bottom of the box. The boxes of cheese are stored in a curing room (fig. 21).

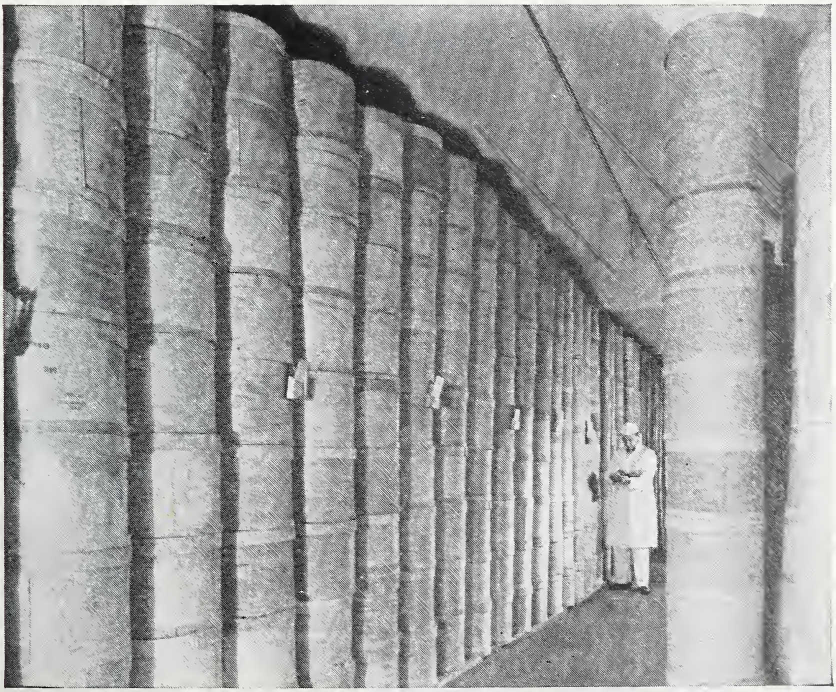

FIGURE 21.—Cheese in boxes in the storage-curing room. The temperature and humidity are regulated carefully throughout the curing period, to provide optimum conditions for the development of the best body and flavor.

GRADING THE CHEESE

The cheese is graded before or when it is sold, and it is sold on the basis of its grade. It often is graded before it is 3 weeks old, although it may be graded also at various times later. In order to have the cheese in condition so that an accurate grade can be obtained before it is 3 weeks old, it should be held at a temperature not lower than 50° F. until it is graded. Just before it is graded it should be warmed up gradually to 60°.

The United States Department of Agriculture has issued United States standards for grades of Cheddar cheese (*39*) that contain specifications for grades applicable to cheese of different ages—that is, fresh, medium cured, and cured or aged cheese: and the Department maintains a Federal grading service which is available to factories on a voluntary basis. In some States the cheese is graded by a State grader.

CURING THE CHEESE

The cheese is cured in insulated, refrigerated curing rooms. Although it usually is boxed and sent to an assembler's warehouse for curing, it may be cured unboxed on shelves at the factory (fig. 22).

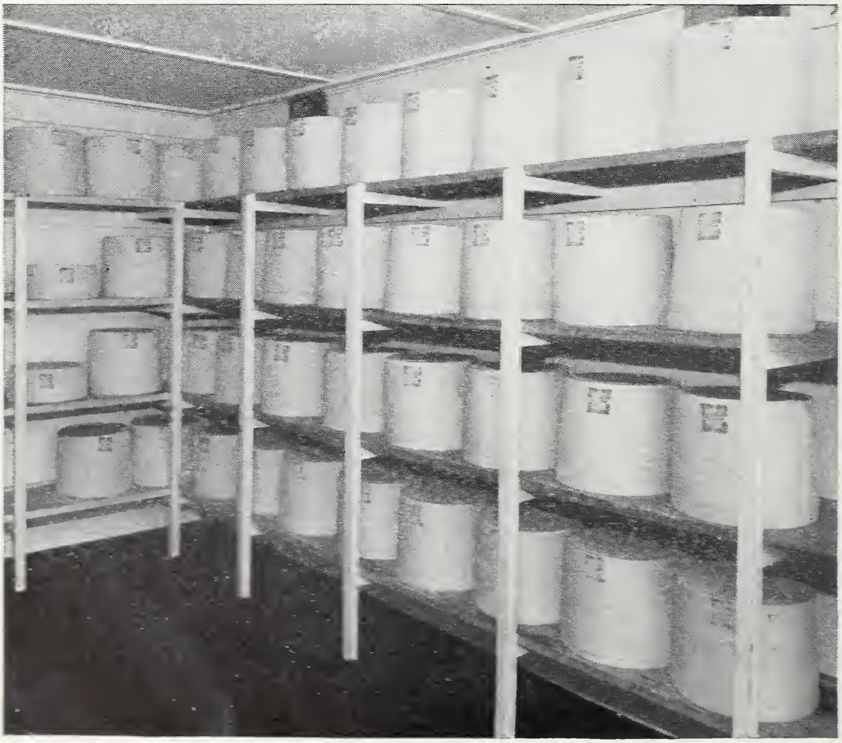

FIGURE 22.—Factory storage and curing of cheese.

The curing period recommended for adequate flavor development is 6 months to a year, although some of the cheese used in making processed cheese is cured for shorter periods. The relative humidity of the curing room should be from 70 to 75 percent, and it should be controlled automatically. The curing temperature likewise should be controlled automatically at a definite temperature, depending principally on the rate of curing desired and the quality of the cheese. The temperature may be between 34° and 60° F., but usually it is between 40° and 50°.

Experiments (*32*) in the Bureau of Dairy Industry have shown that, following a preliminary drying period, cheese of good quality that has been made by the time-schedule method from pasteurized milk of good quality can be cured safely for 3 to 4 months at a temperature as high as 60° F., thus accelerating the rate of flavor development and ripening. The intensity of characteristic flavor of good-quality cheese cured at 60° for 3½ to 4 months was approximately equal to that of similar lots of cheese cured at 50° for 6 months. Shelf curing at a temperature higher than usual, however, results in some additional loss of yield because of evaporation, and special care is required to keep the cheese clean, free of mold and insects, and coated with paraffin or cheese wax. The higher temperatures—higher than 50° or as high as 60°—for more rapid curing should be used only with cheese of superior quality.

Experiments (*44*) in the Bureau have shown, also, that cheese containing excessive moisture, as well as that made from poor-quality milk or having inherent defects, will have better flavor if cured at 40° F. or lower than if cured at 50°. However, at 40° a longer curing period is necessary for adequate flavor development. Temperatures between 32° and 35° induce scarcely any ripening and are used only for storage. The cheese should never be allowed to freeze, because freezing makes the body short and crumbly.

COMPOSITION AND YIELD OF CHEESE

Typical data on the composition of Cheddar cheese are as follows: Moisture, 37 percent; fat, 32.5 percent; fat-in-solids, 51.6 percent; protein, 25 percent; ash, 3.3 to 4.1 percent; and salt, 1.4 to 1.8 percent. A regulation of the Food and Drug Administration, applicable to cheese in interstate commerce, requires that Cheddar cheese contain not more than 39 percent of moisture and not less than 50 percent of milk fat in the solids. Many States have adopted the same regulation.

The yield of cheese varies generally between 9.25 and 11 percent (9.25 to 11 pounds of cheese per 100 pounds of milk), depending on the composition of the milk and also on the manufacturing procedure and the composition of the cheese. For example, tabulations of experimental data have shown the following average yields of cheese containing an average of 37 percent of moisture: 3.5 percent of fat in the milk, 9.32 to 9.45 percent yield; 3.75 percent milk, 10 percent yield; and 4 percent milk, 10.45 to 10.6 percent yield.

The yield of cheese made from pasteurized milk is slightly greater than the yield of cheese made from raw milk. In 46 controlled experiments, Price (*22*, *23*) found that the average increase in yield of cheese due to pasteurization of the milk (holding method) was 0.3 percent. The increased yield resulted from the retention of more fat, moisture, and milk-solids-not-fat in the pasteurized-milk cheese. The percentage of fat in the whey from pasteurized-milk cheese was 0.08 percent less than that in the whey from raw-milk cheese. He reported, also, an average yield of 10.13 percent in the commercial manufacture of cheese from pasteurized milk containing an average of 3.79 percent of fat, and an average yield of 9.72 percent in the manufacture of cheese made earlier in the same factory from raw milk containing an average of 3.68 percent of fat.

Yields were tabulated in 43 controlled, time-schedule experiments in the Bureau of Dairy Industry,[9] in which half of each lot of milk was pasteurized and the other half was not. The milk contained an average of 4.25 percent of fat, and it was standardized to an average of 4.03 percent. The average yield of the pasteurized-milk cheese was 10.89 percent and that of the raw-milk cheese was 10.79 percent.

In experiments in Ontario (*11*), the average yield of cheese made from pasteurized milk was 10.01 percent and that of cheese made from raw portions of the same milk was 9.84 percent. In the same experiments, an average of 90.1 to 91.1 percent of the fat in the milk was retained in cheese made from pasteurized milk, and 88.7 percent was retained in cheese made from raw milk.

Phillips (*20*) obtained an average yield of 9.49 percent, using pasteurized milk containing an average of 3.34 percent of fat. The percentage of fat in the whey from the pasteurized-milk cheese was 0.05 less than that in the whey from raw-milk cheese.

USING WHEY AND BUTTERFAT BYPRODUCTS

In some factories, milk that contains a high percentage of fat is standardized by removing a very small proportion of the fat as cream. Only enough fat should be removed to reduce the percentage of fat in the solids of the cheese to about 51 percent. The cream removed may be sold as cream, or it may be churned to produce butter.

Approximately 88 pounds of whey remains as a byproduct from each 100 pounds of milk used in the manufacture of Cheddar cheese. The whey usually contains from 0.2 to 0.35 percent of fat. The whey may be separated, and usually the whey cream is churned to produce butter.

The fat-free whey usually contains from 4.6 to 5 percent of lactose and lactic acid, approximately 0.8 percent of protein, and also minerals and vitamins. In many factories the whey is returned to the patrons for use as stock and poultry feed. In large factories it may be concentrated or dried. The concentrated or dried whey can be used as a component of various foods, such as cheese food, bakery goods, confections, and sherbets; or it can be used as stock and poultry feed. The whey protein can be precipitated and removed, and used in human foods or in animal feeds. The lactose in fluid whey can be removed and used commercially. Also, it can be fermented to lactic acid, or even to alcohol, for use commercially. Publications on these methods of utilizing the whey are available from the Bureau of Dairy Industry.

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[9] Unpublished data.

LITERATURE CITED

(1) Benson, M.
1915. THE MANUFACTURE OF CHEESE FROM "HEATED" MILK (PT. 2). [Gt. Brit.] Bd. Agr. Jour. 21: 878-889.

(2) ———— and Evans, R. H.
1913. CHEESE FROM "HEATED" MILK. [Gt. Brit.] Bd. Agr. Jour. 20: 281–301, illus.

(3) Brown, L. W., and Price, W. V.
1934. A STUDY OF THE RELATIONSHIPS BETWEEN HYDROGEN ION CONCENTRATION, TITRATABLE ACIDITY, AND QUALITY IN CHEDDAR CHEESE. Jour. Dairy Sci. 17: 33–45.

(4) Dean, H. H.
1898. PASTEURIZING OF MILK FOR CHEESEMAKING. Ontario Agr. Col. and Expt. Farm, 23d Ann. Rpt. (1897): 51–52.

(5) ————
1908. PASTEURIZATION OF MILK FOR CHEESEMAKING. Ontario Agr. Col. and Expt. Farm, 33d Ann. Rpt. (1907): 120–121.

(6) Downs, P. A.
1948. THE MANUFACTURE OF EXPORT-TYPE CHEDDAR CHEESE FROM PASTEURIZED MILK. Nebr. Agr. Expt. Sta. Bul. 390, 32 pp., illus.

(7) Fascetti, G.
1903. ESPERIENZE SULLA FABBRICAZIONE DEI FORMAGGI CON LATTE PASTORIZZATO. Staz. Sper. Agr. Ital. 36: 1004–1008. [Abstract in Expt. Sta. Rec. (1903–04) 15: 1006.]

(8) Freudenreich, E. von
[1892?] EINFLUSS DES PASTEURISIERENS AUF DAS LABEN DER MILCH. Schweiz. Milch Ztg. [Original not seen. Abstract in Fühling's Landw. Ztg. (1892) 41: 759–760, and in Expt. Sta. Rec. (1893–94) 5: 1061.]

(9) Hales, M. W.
1945. CULTURES AND STARTERS. 66 pp., illus. Chr. Hansen's Laboratory, Inc., Milwaukee.

(10) Horrall, B. E., Elliker, P. R., and Kensler, G.
1950. THE USE OF RECONSTITUTED NON-FAT DRY MILK SOLIDS FOR PROPAGATING MOTHER AND BATCH STARTER CULTURES. Jour. Dairy Sci. 33: 250–256, illus.

(11) Irvine, O. R., Bryant, L. R., Hill, D. C., and Sproule, W. H.
1948. A COMPARISON OF THE YIELDS OF CHEDDAR CHEESE OBTAINED FROM RAW, HOLDER PASTEURIZED AND HIGH SHORT-TIME PASTEURIZED MILK. Canad. Dairy and Ice Cream Jour. 27 (11): 49–51. [Abstract in Jour. Dairy Sci. 30 (1947): 530–531.]

(12) Jaggard, G., and Campbell, H. C.
[n. d.] CULTURES AND THEIR USE IN FERMENTED MILK PRODUCTS. Ed. 4, 56 pp., illus. The Dairy Laboratories, Philadelphia.

(13) Janzen, J. J., and Brown, R. W.
1949. CANADIAN CHEDDAR CHEESE FROM PASTEURIZED MILK. Jour. Dairy Sci. 32: 1-9.

(14) Lochry, H. R., Sanders, G. P., and Walter, H. E.
1949. MAKING AMERICAN CHEDDAR CHEESE OF UNIFORMLY GOOD QUALITY FROM PASTEURIZED MILK. U. S. Dept. Agr., Bur. Dairy Indus. BDIM–Inf–73, 8 pp., illus. (Processed.)

(15) Marquardt, J. C.
1929. improving the quality of cheddar cheese by pasteurizing the milk. Food Indus. 1: 305–307, illus.

(16) ——— and Hucker, G. J.
1926. effect of pasteurization and cooling of milk upon the quality of cheddar cheese. N. Y. (Geneva) Agr. Expt. Sta. Bul. 534, 28 pp.

(17) Michaelian, M. B.
1940. the preparation and care of starters. 14 pp., illus. Verley Products Corp., Chicago.

(18) Mohler, J. R., Washburn, H. G., and Doane, C. F.
1911. the viability of tubercle bacilli in cheese. U. S. Dept. Agr., Bur. Anim. Indus. 26th Ann. Rpt. (1909): 187–191.

(19) National Cheese Institute, Inc.
1949. status of pasteurization in cheese factories in the united states. 2 pp. (Processed.) Chicago.

(20) Phillips, C. A.
1928. the effect of flash pasteurization of milk upon the flavor and texture of cheddar cheese. Jour. Dairy Sci. 11: 292–298.

(21) ———
1935. bitter flavor in cheddar cheese made from pasteurized milk. (Abstract) Jour. Dairy Sci. 18: 471–472.

(22) Price, W. V.
1927. the manufacture of cheddar cheese from milk pasteurized by the holder method. N. Y. (Cornell) Agr. Expt. Sta. Mem. 105, 36 pp., illus.

(23) ———
1927. cheddar cheese from pasteurized milk. Jour. Dairy Sci. 10: 155–168.

(24) ———
1944. cheddar cheese from pasteurized milk. Wis. Agr. Expt. Sta. Bul. 464, 16 pp., illus. (Rev. 1945.)

(25) ———
1949. how to make good lactic starter. Wis. Agr. Col. Ext. Cir. 383, 16 pp., illus.

(26) ——— and Prickett, P. S.
1928. a comparison of three methods of pasteurizing milk for cheddar cheesemaking. Jour. Dairy Sci. 11: 69–78.

(27) Publow, C. A.
1910. fancy cheese in america. 96 pp., illus. American Sheep Breeder Co., Chicago.

(28) Russell, H. L.
1916. pasteurized milk cheese. Wis. Agr. Expt. Sta. Bul. 268 (Ann. Rpt., 1915): 34–36.

(29) Sammis, J. L.
1948. cheesemaking. 314 pp., illus. Cheese Maker Book Co., Madison.

(30) ——— and Bruhn, A. T.
1912. the manufacture of cheddar cheese from pasteurized milk. Wis. Agr. Expt. Sta. Res. Bul. 27: 137–248, illus. [See also U. S. Dept. Agr., Bur. Anim. Indus. Bul. 165, 95 pp., illus. 1913.]

(31) Sanders, G. P., and Sager, O. S.
1947. phosphatase test for various dairy products. Jour. Dairy Sci. 30: 909–920. [See also Jour. Assoc. Off. Agr. Chem. 31 (1948): 306–318.]

(32) ——— Tittsler, R. P., and Walter, H. E.
1946. the rapid ripening of cheddar cheese made from pasteurized milk. U. S. Dept. Agr., Bur. Dairy Indus. BDIM-Inf-29, 4 pp. (Processed.) [Summary in Natl. Butter and Cheese Jour. 37 (4): 46, 47.]

(33) Spicer, D. W., and Burgwald, L. H.
1935. PREDICTING ACID DEVELOPMENT IN CHEDDAR CHEESE DURING STORAGE. Natl. Butter and Cheese Jour. 26 (21): 14, 16, 33–34.

(34) Stevenson, C.
1920. PASTEURIZATION IN CHEESE-MANUFACTURE. New Zeal. Jour. Agr. 20: 5–9, illus.

(35) ————
1924. PASTEURIZATION OF MILK FOR CHEDDAR CHEESE MAKING IN NEW ZEALAND. Proc. World's Dairy Cong., Washington, D. C. (1923) 1: 306–308.

(36) ———— and Grant, W.
1916. PASTEURIZATION OF MILK FOR CHEESEMAKING. New Zeal. Dept. Agr. Jour. 12: 440–445, illus.

(37) Stine, J. B., Loos, H., and Daume, H. E.
1949. THE EFFECT OF COPPER ON THE QUALITY OF CHEDDAR CHEESE AND CHEESE FOODS. Proc. 12th Internatl. Dairy Cong., Stockholm 2 (2): 350–356, illus.

(38) Thom, C., and Fisk, W. W.
1938. THE BOOK OF CHEESE. Rev. ed., 415 pp. The Macmillan Co., New York.

(39) United States Department of Agriculture.
1950. UNITED STATES STANDARDS AND GRADES OF CHEDDAR CHEESE. U. S Dept. Agr., Prod. and Mktg. Admin., unnumbered pub., [6] pp. (Processed.)

(40) Van Slyke, L. L., and Price, W. V.
1949. CHEESE. Rev. ed., 522 pp., illus. Orange Judd Pub. Co., New York.

(41) Walter, H. E., and Lochry, H. R.
1945. THE MANUFACTURE OF CHEDDAR CHEESE FROM PASTEURIZED MILK IN COMMERCIAL PLANTS. Jour. Dairy Sci. 28: 597–606, illus.

(42) Wilson, H. L.
1941. THE MANUFACTURE OF AMERICAN CHEDDAR CHEESE FROM PASTEURIZED MILK. U. S. Dept. Agr., Bur. Dairy Indus. unnumbered pub., 10 pp. (Processed.) [Also in Natl. Butter and Cheese Jour. 32 (2): 18, 20, 22, 24, 27, 28. 1942.]

(43) ————
1942. MAKING AMERICAN CHEDDAR CHEESE OF UNIFORMLY GOOD QUALITY. U. S. Dept. Agr., Bur. Dairy Indus. BDIM-947, 9 pp., illus. (Processed.)

(44) ———— Hall, S. A., and Johnson, W. T., Jr.
1941. RELATIONSHIP OF CURING TEMPERATURES TO QUALITY OF AMERICAN CHEDDAR CHEESE. Jour. Dairy Sci. 24: 169–177, illus.

(45) ———— Hall, S. A., and Rogers, L. A.
1945. THE MANUFACTURE OF CHEDDAR CHEESE FROM PASTEURIZED MILK. Jour. Dairy Sci. 28: 187–200, illus.

(46) Wilster, G. H.
1951. PRACTICAL CHEDDAR CHEESE MANUFACTURE AND CHEESE TECHNOLOGY. Ed. 7, 515 pp. Oregon State College Co-op. Assn., Corvallis.

(47) ———— and Price, F. E.
1940. PREPARATION OF STARTER FOR CHEESE, CULTURED BUTTERMILK, AND BUTTER. Oreg. Agr. Expt. Sta. Bul. 379, 24 pp., illus.

☆U. S. GOVERNMENT PRINTING OFFICE: 1951—948248

For sale by the Superintendent of Documents, U. S. Government Printing Office
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